FOUNDRY TRADE JOURNAL
EST. 1902
WITH WHICH IS INCORPORATED THE IRON AND STEEL TRADES JOURNAL
VOL. 101
No. 2082
Registered at the G.P.O. as a Newspaper
SEPTEMBER 6, 1956
Offices: John Adam House, John Adam St., London, W.C.2
Single Copy, 9d. E
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FOUNDRY TRADE JOURNAL

Established 1902

Vol. 101 Thursday, September 6, 1956 No. 2082

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PRINCIPAL CONTENTS

Technical :

PAGE

Basic Principles Applicable to Steelmaking in Founding Practice, by T. A. Cosh and R. J. Sarjant: Communication from the British Steel Castings Research Association, presented at the annual conference of the Institute of British Foundrymen in Cardiff last June, in which an examination is made of the physical chemistry of steelmaking . 251

CO_2 Process: Formation and Dissolution Mechanism in Relation to the Silicate Bond, by C. Starr: The chemical nature of the sand/silicate bond for making cores and moulds is discussed and the effects of three groups of metal casting temperatures described. Differences in breakdown of spent moulds are considered, and the desirable qualities of an ideal additive to improve breakdown are given 265

Features :

Leader: International Foundry Congress . 247
Featuring Sir Percy Mills . . 248, 249
Publications Received (Advert section) 39

Commercial :

Company News, New Patents and Contracts Open 268
Raw Material Markets 274
Current Prices of Iron, Steel and Non-ferrous Metals 276

AN INDUSTRIAL NEWSPAPER PUBLICATION

Published Weekly

Single copy 9d.; by post 1s.
Annual subscription : home 40s., abroad 45s. (prepaid).

17/19 JOHN ADAM STREET, ADELPHI, LONDON, W.C.2

'Phone: TRAfalgar 6171 (10 lines)
'Grams: Zacatecas, Rand, London.

International Foundry Congress

An American Professor of English History staying in a Düsseldorf hotel asked us what *Giesserei Fachmesse* meant. The answer was that it literally meant "foundry technical fair." This question must have been asked by the whole of the permanent and floating population of this essentially modern city, for everywhere one encountered publicity for it. Moreover, the exhibition buildings, situated on a wide boulevard running alongside the Rhine, arrest the attention of the passer-by through the display of a 250-ton rolling mill housing and large manganese propellers.

Both the exhibition and the Congress are of record dimensions—if not for the whole world—at least for Europe, as the following figures will show: no fewer than 3,500 foundrymen from 30 different countries have registered for the Congress, whilst a total of 10,000 are to visit the exhibition. In the exhibition, over 500 firms are showing, either the products of the foundry, or the machines and raw materials they use. In the short time at our disposal, we were able to appreciate during a preview the international character of the exhibition.

The opening ceremony was held under the presidency of Dr. Schwietzke, the president of the German foundry technical association, in the vast, circular Rheinhalle. With him on the platform, beautifully adorned with a profusion of flowers, were Mr. M. Vuilleumier, the president of the International Committee, Dr. Everest, the vice-president, Mr. Lambert, secretary, and the official representatives of all the participating countries. First a sonata was played and then there were the addresses of welcome by the two presidents, with extracts in both French and English. Then there was a speech by Mr. W. Hövelman, the chairman of the foundry industries association, who gave many interesting facts about the foundry industry of his country. On behalf of the German foundrymen's technical association, Dr. Schwietzke presented awards of honorary membership—the first in its long history to Mr. J. H. Küster, who for so many years has occupied, and has only recently vacated, the presidential chair of the association; Mr. Max Vuilleumier, the popular president of the International Committee, and Mr. V. C. Faulkner, the Editor of the FOUNDRY TRADE JOURNAL. It is now usual to introduce into foundry conferences a lecture by an outstanding expert on a phase of science and art not directly connected with our own industry. In Düsseldorf, a Professor of Biology, Dr. H. Meessen, showed the need to investigate the biological effect upon man of technological developments. Finally, the Lord Mayor of Düsseldorf, in a witty speech, formally opened the exhibition.

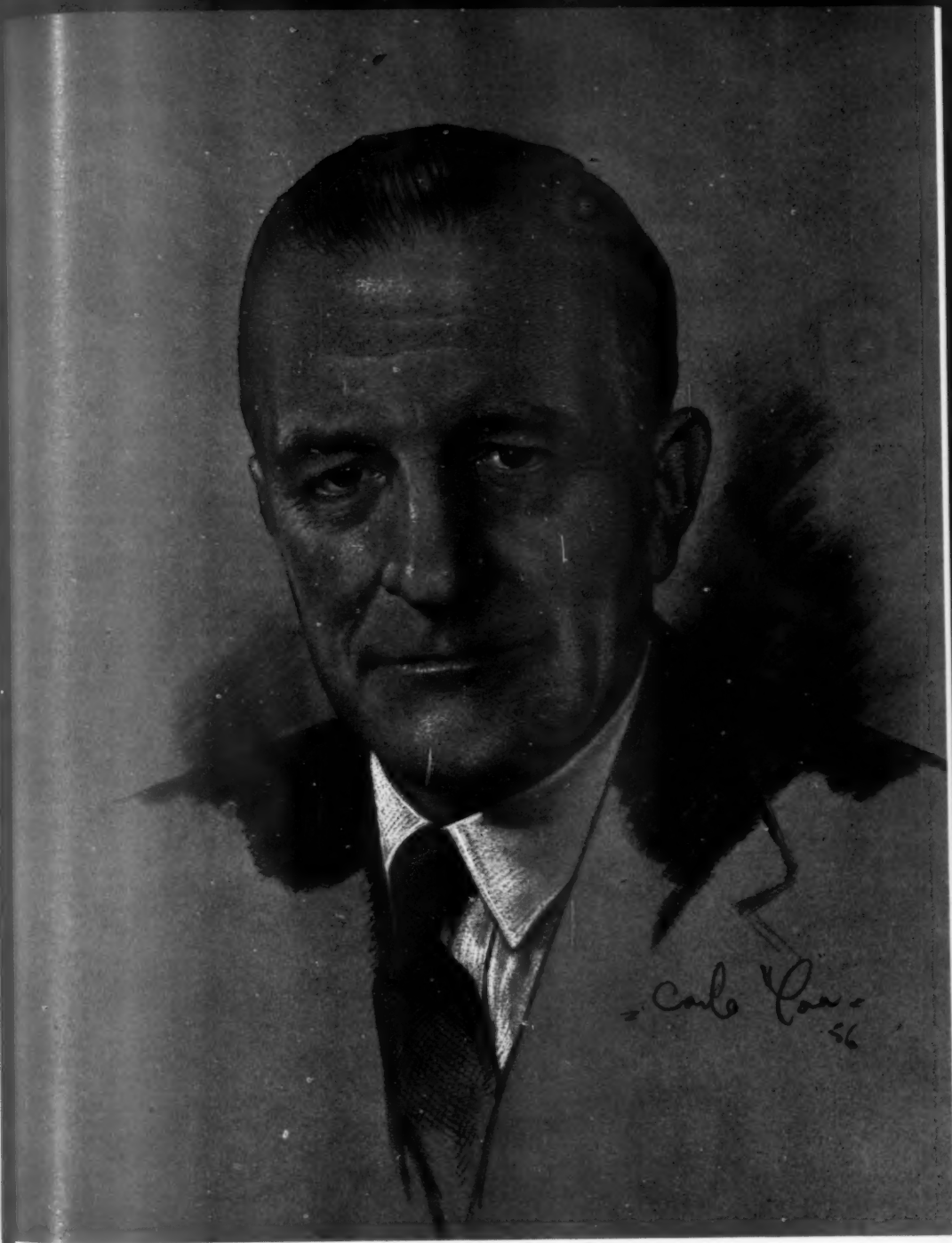
Featuring . . . .

SIR PERCY HERBERT MILLS, Bt., K.B.E.

SIR PERCY MILLS has been associated with W. & T. Avery, Limited, since 1919. His ability was early recognized, for within five years he became general manager and promotion to managing director came six years later. Finally, in 1955, he was appointed chairman of the organization. The group has made consistent progress under his direction, and the firm's new Tame Bridge foundry (completed last year), which ranks amongst the finest in the world, is a fitting recognition of the fundamental part played by the foundry in the industrially-important scale industry. His policy, including as it does, social progress—Sir Percy was a pioneer in the institution of holidays with pay—has ensured that the bathing, washing and clothes changing facilities at Tame Bridge are of the highest quality.

It was only to be expected that when the war broke out the Government would call upon Sir Percy's services. His many appointments included Deputy Director of Ordnance Factories; Controller-General of Machine Tools; and head of the production division of the Ministry of Production. When hostilities ceased, his services were retained as president of the Economic Sub-commission of the British Control Commission for Germany. Other public work has included membership of the advisory council of the Exports Credits Guarantee Department; presidency of the Association of British Chambers of Commerce; chairmanship of the National Research Development Corporation; and adviser to H.M. Government on the housing programme.

One of Sir Percy's activities which has won high approbation is the great personal interest he has taken in increasing the status of the foremen, affected as they have been in recent years by the encroachment on their preserves by a multitude of specialists in labour management. These efforts were recognized last year by the bestowal by the (American) National Association of Foremen of the International Edward O. Seits Award for management. His public work has been attested by his being created a knight and, later, a baronet.



SIR PERCY HERBERT MILLS, Bt., K.B.E.

Chairman, W. & T. Avery, Limited.

Massive Hammer-block Casting

What is believed to be the largest steel casting made for a forging-hammer block in this country was recently installed in the axle forge at the works of Steel, Peech & Tozer, Rotherham, a branch of the Unitel Steel Companies, Limited. The £15,000 casting, which has a machined weight of 143 tons, was made at the Grimesthorpe steel foundry of English Steel Castings Corporation, Limited, Sheffield, for B. & S. Massey, Limited, Openshaw, Manchester, the builders of the 7-ton forging hammer.

The new hammer block, a one-piece steel casting, replaces an 82-ton two-piece block consisting of an upper section in steel and a lower section in iron, the two being dovetailed and keyed together. In service, it was found that the two sections of the block were beginning to work loose, causing a deterioration in the quality of the axles being forged due to slight lateral and longitudinal movements of the block, which is independent of the hammer itself. In addition, maintenance costs were becoming excessive. As a stable base is essential for high-quality forging, it was therefore decided to instal the new and heavier single-piece block, giving a ratio of block to hammer of 20:1, compared with a ratio of 12:1 with the former block.

Detail Planning Necessary

The delivery and installation of this massive casting called for careful advance planning and was arranged to coincide with the annual holiday weeks at Steel, Peech & Tozer. Two days beforehand, the casting was loaded (Fig. 1) on to a heavy motor trailer at the River Don Foundry and transported for three miles to the Templeborough melting shop of Steel, Peech & Tozer, where a 150-ton overhead crane transferred it to a special railway wagon supplied by British Railways. The railway authorities had previously strengthened a bridge and rail tracks across the River Don so that the casting could be safely delivered to the axle-forge building.

Production in the forge ceased at 1 p.m. on the Friday for the annual holiday, and work began immediately on dismantling the forging hammer completely. The old block was removed, the new one placed in position and the entire hammer rebuilt by 10 p.m. on Sunday, two weeks later, ready to resume operations the next morning when production at the works recommenced. It is interesting to note that this major replacement was carried out entirely by members of Steel, Peech & Tozer's staff, due to the strike of maintenance craftsmen which was then in progress. Soon after resumption, it was apparent that the anticipated improvement in quality of the railway wheel-axles was being achieved, and it is expected that higher output will result from the quicker reaction and better impact between hammer and block.

FIG. 1.—*Cast-steel hammer-block weighing* 143 *tons, made by English Steel Castings Corporation, Limited, for B. & S. Massey, Limited, Openshaw, Manchester.*

Production Engineers' Awards

The Institution of Production Engineers announce the following awards to be made at the annual dinner on October 5, 1956:—*Silver Medal for the best paper presented by a member in the* 1954/55 *session*—Mr. R. N. Marland, B.SC., director and works manager, John Wright & Company, Limited, for his paper: "A Job Evaluated Wages Structure."

Silver Medal for the best paper presented by a non-member, in the 1954/55 *session*—Mr. J. A. Stokes, B.SC., and Mr. N. Milne, B.SC.(ENG.), both of the electronics engineering department, British Thomson-Houston Company, Limited, for their joint paper: "Electronics as an Aid to Production."

Lord Austin Prize, 1954/55—Mr. S. A. Onions, senior planning engineer, Wilmot Breedon, Limited, for his paper: "Welding Distortion Problems Encountered in the Gas-turbine Industry."

Latest Foundry Statistics

The Council of Ironfoundry Associations states that the number of ironfoundry workers employed in the United Kingdom during the week ending June 30, 1956, was 143,343, made up of 133,184 males and 10,159 females. This shows a reduction of 1,423 on the May figures and 506 on those of a year ago.

According to the Ministry of Supply the output of aluminium castings in June was 2,005 tons from sand moulds; 3,610 tons as gravity-die, and 1,221 tons as pressure-die-castings.

Index to Vol. 100

The index to the JOURNAL, volume 100, covering the period January to June, 1956, has now been printed and is available to readers free of charge. Applications for copies should be addressed to the publishing office, FOUNDRY TRADE JOURNAL, John Adam House, John Adam Street, Adelphi, London, W.C.2. Subscribers who wish to receive copies of the indices as they are printed may apply for inclusion on a permanent mailing list. Those already on this list need not apply for their current copy.

Basic Principles Applicable to Steelmaking in Founding Practice*

By T. A. Cosh, B.Sc., A.R.T.C., F.I.M. and R. J. Sarjant, O.B.E., D.Sc., F.I.M.

In the course of the last few decades, considerable attention all over the world has been devoted to the physical chemistry of steelmaking, and substantial literature on the subject exists. This body of knowledge is not as widely applied in a practical sense as it might be. It involves a fairly deep acquaintance with fundamental mathematical and physical principles, requiring almost a specialist standard of knowledge. Further, the problems associated with the everyday matters of the melting shop do not lend themselves readily to the precision of measurement required by this somewhat involved branch of science. Nevertheless, the laws of physical chemistry have an extremely important bearing on steelmaking practice and, therefore, this effort has been made to pick out the more important features of special interest which emerge from the classical researches in the field. The objective of the present Paper is to examine some aspects of the subject that may be of interest to the steelfounder.

Essential features of the steelmaking operation are the reactions in the bath that occur between the metal, the refractories that contain it and, more specifically, the slag. The physical chemistry of these reactions is sufficiently developed to provide a reasonably secure basis for real understanding of steelmaking operations. The most-important laws involved in this context are the ideal law of mass action, which governs the course of the reactions between components of slag and metal and determines the final state of equilibrium in the molten bath, and two others, Nernst's partition law and Henry's absorption law, which are concerned with the concentrations which are attained by the reagents in the various phases of the reaction, gas, metal, slag and hearth. Specific details of these laws are explained in the Appendix. Further, the phase diagram may be described as the skeleton structure upon which the kinetics of the subject is built. Examples of the use of the various principles involved are given in the following comments in which an attempt to look at the problem from the steelfounders' viewpoint has been the major consideration.

Type of Process

Whilst all types of steelmaking plant have been applied to steel-founding practice, in recent years trends have been towards the greater use of the electric-arc method, more particularly the basic process, for those processes involving refining as distinct from melting. Electric-arc processing now accounts for over 60 per cent. of the total steel produced for castings, as compared with less than 15 per cent. in 1920. Whilst the principles to be dealt with have a universal or specific applicability according to their character, attention has been focused rather on the basic electric-arc furnace, where the process has features in which scientific control can be applied to a high degree. The method of approach has been to follow the course of a melt, and explain the relations between the salient practical features and the theoretical principles involved.

Melting Period

With steel, although the melting operation is primarily intended to be a direct transmission of heat to bring about fusion, the operation is in fact not by any means simple. There are a multitude of reactions going on during melting that may materially determine the general character of the melted metal. Thus, there is oxidation from the furnace atmosphere, which will vary according to the character of the scrap, whether heavy or light, clean, scaled or rusty. The carbon-dioxide from the limestone added as a flux is a minor oxidizing agent. There may be a carbonaceous addition to the charge for purposes of adjusting composition, usually of coke or electrode carbon, anthracite being avoided in processes in which dissolved hydrogen may be an undesirable constituent. In the early stages of melting, the character of the slag is first formed, an

*Official contribution from the British Steel Castings Research Association, presented at the annual conference of the Institute of British Foundrymen in Cardiff last June.

PROFESSOR R. J. SARJANT has long been connected with the activities of the iron, steel and fuel industries. For some years he was a local director of Hadfields, Limited, Sheffield, and then was appointed to the Chair of Fuel Technology at the University of Sheffield. Recently, he took over temporarily as director of the British Steel Castings Research Association. He was awarded the Melchett Medal of the Institute of Fuel in 1950, made an O.B.E. in 1946, and Emeritus Professor of the University of Sheffield in 1953.

MR. COSH was born in Glasgow where he attended Hutchesons' Boys' School. In 1935 he joined the laboratory staff at Dixon's Ironworks and later transferred to the Empire Aluminium Company, Limited. During the war, he was commissioned in the Highland Light Infantry and on demobilization became a full-time student of the Royal Technical College and Glasgow University. In 1950 he was appointed works metallurgist to Jarrow Tube Works, Limited, and in 1952 joined the staff of the British Steel Castings Research Association.

important practical factor in its determination being the condition of the furnace bottom, particularly the standard of fettling and its shape to ensure adequate drainage. Such conditions are determined by the nature of the ramming of the bottom refractory, the composition of the scrap, the fluxes used and the effectiveness of fettling at the furnace slag line, the banks and the bottom.

Furnace Hearth

The changes that take place on a hearth during melting and refining were the subject of considerable investigation by the Basic Furnace Linings Committee of the Iron and Steel Institute in a series of co-operative investigations undertaken during the war, when the shortage of imported magnesite made the enquiries necessary[1]. Iron oxide originates from the oxidation of metal pools left on the hearth

FIG. 1.—*Phase diagram for the system CaO/Fe₂O₃ (Sosman & Merwin).*

owing to insufficient drainage. This forms compounds with lime (see Fig. 1) which are fluid at relatively low temperatures. Any silica from roof brickwork or slag left after tapping the previous charge, reacts with the lime in the hearth to form tri-calcium silicate ($3CaO.SiO_2$)—which is quite refractory—while the iron oxide and alumina tend to form solid solutions with lime of the brown-millerite ($4CaO.Fe_2O_3.Al_2O_3$)/dicalcium ferrite ($2CaO.Fe_2O_3$) type, which have low melting points and tend to penetrate deeply into the hearth and banks of the furnace. The pertinent phase-diagram due to Sosman and Merwin[2] (Fig. 1) indicates the low melting points of the ferrites formed. The superior quality of MgO over CaO, as a bottom-forming material may be shown from the pertinent phase-diagrams. Compounds of MgO, CaO, SiO_2 with low concentrations of SiO_2 and a dominance of MgO are highly refractory (1,400 deg. C. +). A prepared mix of MgO, Fe oxides, lime and silica present as impurities, having 60 to 85 per cent. MgO makes an excellent hearth refractory. Of all the steelmaking refractories, MgO is the most resistant to liquid iron-oxide. It can absorb its own weight of iron oxide before it shows signs of melting under steelmaking conditions, the reason being that $MgO.Fe_2O_3$ is a true spinel and forms a continuous series of solid solutions with Fe_3O_4, whereas calcium ferrites are not true spinels and do not form solid solutions with Fe_3O_4. The liquidus curves, or curves at which melting begins, run from just under 1,600 deg. C. for Fe_2O_3 to 1,780 deg. C. for an absorption of only 20 per cent. of Fe_2O_3 at which the compound magnesio-ferrite, $MgO.Fe_2O_3$, is formed.

Heat Requirements

The heat required in the process of melting is dependent upon the specific heats and the latent heat of fusion of the constitutents of the charge. The heat capacity over a range of temperature normally rises with temperature according to a relation expressed by the equation:

$$Cp = a + bT - cT^{-2} \quad \ldots\ldots\ldots(1)$$

where Cp=molar heat capacity and T=abs. temp. The constants a, b, and c vary for every material, but they are known with some accuracy, so that it is only a matter of looking up the pertinent tables to be able to determine the energy requirements with considerable accuracy. In any chemical reaction, there is always involved a change of energy. Accordingly, in the process of melting down, there are the exothermic reactions of oxidation of Fe, C, Mn, Si and metalloids. Generally the oxide-forming reactions are exothermic, and the reducing actions, endothermic, or heat absorbing. The major endothermic-reactions during melting involve decomposition, such as of limestone or water (at the highest temperatures). The slag-forming reactions at this stage are to a minor degree exothermic. The heats of reaction can be calculated from the equilibrium constants and these can in turn be determined from the analytical data observed in the course of a reaction, which shows on reversal a momentary equilibrium. One of the real difficulties in applying the fundamental laws in this field is that in practice, equilibrium is rarely attained, and, therefore, the trends towards equilibrium have to suffice. By observing trends from two opposite directions in a given reaction, the data relating to the stage of equilibrium may be obtained[3].

Gas Absorption

Molten metal and slags have a high solubility for gases, the amount of gas dissolved at a given temperature being proportional to the square root of the pressure (Sievert's Law). The significance of the gas content of the molten steel at pouring is well recognized. Accordingly, the sources of dissolved gases require to be controlled. The best way to avoid hydrogen is to keep out of the charge moisture, rust and hydrated substances such as slaked lime and coal. Ferro-alloys have been known to form a source of the gas, particularly types that can react with water, giving hydrogen capable of being absorbed in any microporosity. This may arise from weathering of the alloy. An indication of the gas content of ferro-alloys in common use is given in Table I.

Thus, each 1 per cent. addition of high-carbon ferro-manganese will increase the hydrogen con-

TABLE I.—*Hydrogen Content of Ferro-alloys.* (*William Jessop & Sons Limited*)

Nature of alloy.	Hydrogen content ml. at N.T.P. per 100 gm.
75 per cent. ferro-silicon	6.1
45 per cent. ferro-silicon	5.4
High-carbon ferro-manganese	23.5
Low-carbon ferro-manganese	13.8
Silico-manganese	7.1
0.1 per cent. carbon ferro-chrome	1.9
4 to 6 per cent. carbon ferro-chrome	2.7
Ferro-molybdenum	1.1
Nickel shot	3.0

tent by 0.2 ml. per 100 gm. of steel. This small amount becomes significant and important in the manufacture of austenitic manganese-steels containing 11 to 14 per cent. manganese.

In addition to the unsoundness which results from gas evolution as a casting solidifies, there is also an adverse effect on physical properties. The effect of nitrogen on physical properties is probably most noticeable in steel made by the Bessemer process and much research has been conducted in order to minimise the content of this gas in steel made by that process. In some respects, the presence of nitrogen is regarded as advantageous, for instance, for the purpose of improving machinability, where its value is ascribed to the embrittlement of the machined chips, which makes them break more readily. In steel castings, one of the most detrimental features of nitrogen is its tendency to combine with aluminium to form aluminium nitride as a grain-boundary constituent and to be largely responsible for "rock candy" fracture.[4] The calculated equilibrium constants of the reactions of nitrogen with titanium and zirconium are very low at steelmaking temperatures, suggesting their possible de-nitrifying action. This has been demonstrated in practice by numerous observations.

Oxygen is a major reagent in steelmaking operations. The equilibrium content of oxygen depends mainly on the carbon/oxygen reaction, but it does not come to equilibrium in practice and, therefore, the bath normally contains an excess of dissolved oxygen, as FeO. A reasonably high oxygen-potential in the bath as melted is necessary for effective phosphorus removal.

The question thus arises as to how detrimental gases may be avoided. The gas pick-up may be influenced by the furnace design, that is, the ratio of bath area to bath depth. The design of the electric furnace has been largely traditional, being determined by the requirements of the electrical power and tilting provisions. Some typical figures of well-designed units are given in Table II.

TABLE II.—*Bath Dimensions of Electric-arc Furnaces.*

Nominal capacity. tons.	Bath diameter. ft. in.	Bath depth. in.
2	4 2	13
3½	5 4	14
4½	6 2	18
6½	7 2	19
8½	8 0	20
12	9 0	22
15	9 10	23
19	10 10	25

Since gas absorption may be a function of time as well as temperature, it would be expected that a rapid melt, provided there was adequate slag protection would result in a reduced gas-content. Thus, the question of transformer capacity arises. Transformer capacity must obviously be determined by a combination of design factors; it may be of the order of 600 kva. per ton for a furnace of 3 tons capacity, 450 kva. for one of 15 tons and 250 kva. for 60 tons.

Drying of the Charge

Reverting to the question of hydrogen absorption, the moisture content of slag-forming materials

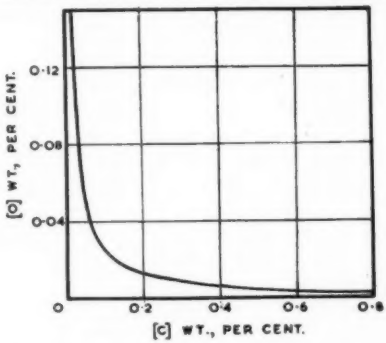


FIG. 2.—*Equilibrium between carbon and oxygen at* 1,600 *deg. C.* (*Vacher & Hamilton*).

is significant. A statement of the typical content of moisture in slag-forming materials is given in Table III. In this context, there arises the question

TABLE III.—*Moisture Content of Slag-making Materials.*

Material.	Moisture, per cent.
Limestone—as received	0.36
Lime-free moisture	0.14
Lime (old stock)—combined water	17.50
Fluorspar—as received	0.75

of the choice of limestone or lime as fluxes. It has been observed that basic-electric steels made with calcined lime show more unsoundness in a cast ingot than steels made with limestone.

Decomposition of Limestone

The decomposition of limestone into lime and carbon dioxide is endothermic and requires 78.5 B.T.U. per lb. However, to raise the products to 1,550 deg. C., the overall heat required is 59,740 B.T.U. per 100 lb. of limestone. From this 100 lb., only 56 lb. CaO is produced, but this quantity of lime requires to raise it to 1,550 deg. C. only 49,350 B.T.U. The use of lime, therefore, gives an effective saving of 185 B.T.U. per lb. slag lime. Nevertheless, the choice of lime instead of limestone is only economically effective when it is used dry. Another physical effect of using limestone rather than lime is that the reaction resulting from the addition increases the rate of

heat-transfer sufficiently to prevent any marked temperature drop. Slag can digest raw limestone at a lower temperature than is required to flux burnt lime.

It is only when the melting-down stage has been completed that the composition of the bath becomes known. At this stage, the slag consists mainly of lime (CaO), silica (SiO_2) and oxides of iron (FeO and Fe_2O_3) together with smaller amounts of MgO, MnO and Al_2O_3. Unlike open-hearth practice, where the slag composition is an essential criterion of the subsequent procedure to be pursued, scant attention need be paid to the slag composition at this stage of the melt in the electric arc furnace process, because of the flexibility of the control.

Estimation of Slag Composition

At this stage of the process, for normal control purposes the chemical composition of the slag can-

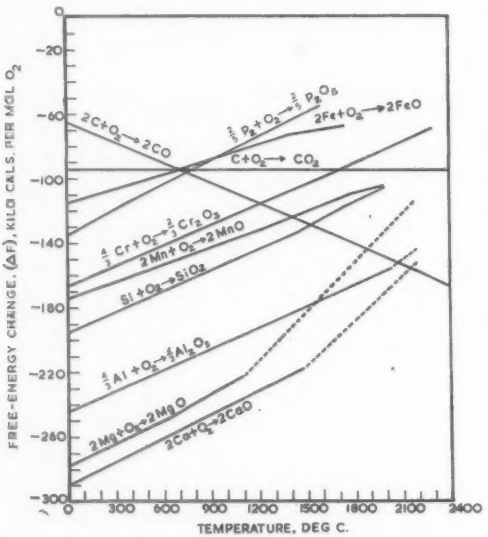


FIG. 3.—*Ellingham diagram indicating the change in stability of oxides with temperature (Richardson & Jeffes).*

not be obtained by normal chemical methods, but there are physical and visual methods that can be serviceable. In the basic process, there is a fairly close relationship between silica and ferrous oxide before the lime "boil," which makes it possible to estimate the silica content from a rapid FeO analysis[3]. Slag fluidity, which may be rapidly determined in a practical way, varies with composition and with temperature. The oxidized slags usually met with at the "melted" stage exhibit, however, certain mineralogical characteristics which assist in a broad, rapid assessment of composition. In quenched samples, the FeO content and the $CaO:SiO_2$ ratio may be roughly estimated[4], from colour, which varies from grey for low FeO and low CaO:SiO to black for medium-FeO for the same basicity. The higher contents of FeO and increased $CaO:SiO^2$ ratios give a deepening of colour from a light-brown shade through a dark brown to a chocolate brown for the highest value of these constituents. Colour differences are more easily observed by using powdered slag, sieved to a uniform grain-size, and obtained from a specimen slowly cooled in the sampling spoon. Segregation of spinels and olivine-type minerals is revealing, if a sample taken from the centre of the cooling mass and so treated, is examined under the microscope. The silica can be quickly and roughly estimated on certain types of slag by noting the degree of silica-gel formation in solution in hydrochloric acid. Any system of reading slag samples visually or by any other means should be checked by chemical analysis, since furnace practices may differ. Additions of fluorspar may vitiate accuracy of estimation. Methods have been suggested for making quantitative measurements, either by means of photo-electric cells and reflected light or magnetic susceptibility.

Oxidation Period

The control of the chemical composition of the bath is ultimately associated with slag control. When excessive amounts of sulphur and phosphorus are present, their concentration may govern the course of the refining operation. Of these, in the basic electric furnace, the phosphorus alone requires consideration in the oxidation period. Wide variations occur in slag composition from melt to melt, even in successive melts made by the same furnace operators. The figures shown in Table IV illustrate this point.

TABLE IV.—*Comparison of Slag and Metal Composition of Steel as First Melted by the Same Operator on Three Successive Melts.*

Melt.	Slag composition, per cent.				Metal composition, per cent.	
	(SiO_2)	(FeO).	(CaO).	(MgO).	[P].	[C].
A	6.81	59.74	21.15	9.19	0.009	0.07
B.	16.64	18.80	35.98	14.89	0.028	0.20
C. ..	19.20	9.26	59.52	6.73	0.033	0.29

Phosphorus Removal

From a consideration of these figures, the basic physico-chemical principles of phosphorus oxidation may be illustrated. The partition law developed by Henry, Dalton and Nernst states simply that one type of molecule tends to partition between two solvents such that the ratio of the concentrations is constant at a given temperature. Accordingly, in the above case, excluding recondite arguments about the activity of a separate constituent of a slag, there is constant partition of the FeO between slag and metal. The higher the (FeO) in the slag, the higher will be the [FeO] dissolved in the molten metal—the use of the round and the square brackets defines whether the constituent FeO is dissolved in the slag (FeO) or in the liquid metal [FeO]. The next question is the relationship in the liquid steel between the [FeO] and the

[C], since there can be a reaction between the two, thus

$$C + FeO \rightleftharpoons Fe + CO \quad \ldots\ldots\ldots \quad (2)$$

which depends upon concentration of the reactants and temperature. Now as the [FeO] increases, the amount of carbon in the metal in equilibrium with the high [FeO] in melt A will be extremely low[7] as shown in Fig. 2. The extremely high slag (FeO) of this melt suggests that the phosphorus has probably already been reduced to a fairly low figure during melting. With this particular slag at a temperature of, say, 1,550 deg. C. it can be expected that the bath sample will be very low in both phosphorus and carbon. The relationships between the slag and metal compositions are evident from Table IV and confirm this expectation. The figures in the Table refer to the metal and slag before any normal boiling has taken place. They indicate the conditions requisite to the removal of phosphorus.

The course of any chemical action in a bath of molten steel proceeds according to the activity or concentration of the reactants until a state of equilibrium is reached, after which it can go no further as long as the temperature and other conditions remain constant. This equilibrium state is determined by the free energies of the reactants and the products. It is, therefore, imperative to obtain reliable data on the free energies of the various chemical compounds at steelmaking temperatures.

Much of the information on the free energy of compounds is derived from measurements of their heat of formation and heat capacity, and from

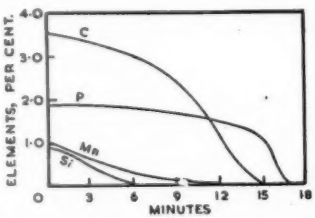


FIG. 4.—*Representation of the progress of a melt in a Bessemer Converter.*

the application of the third law of thermodynamics, or Nernst's heat theorem. The technique of determining the pertinent values is described briefly in the Appendix.

Accepting, therefore, the information available as applicable to the present problem, for the oxidation of phosphorus according to the reaction:—

$$2P + 2\tfrac{1}{2}O_2 \rightarrow P_2O_5 \quad \ldots\ldots\ldots\ldots \quad (3)$$

investigation shows that for this reaction the free energy of formation $\triangle F$, of P_2O_5 is given by [8]

$$\Delta F = -370{,}000 + 123.43T \quad \ldots\ldots \quad (4)$$

where T is the temperature in deg. K.

If $\triangle F$ for this reaction is plotted for various temperatures the line shown in Fig. 3 is obtained. Points to note regarding this reaction, which are applicable to all the other oxidizing reactions shown on the diagram except the reactions involving carbon, are:—

(i) The oxidizing reaction is exothermic, *i.e.* an increase in temperature tends to oppose the reaction (by the Le Chatelier principle).

(ii) As the temperature increases, the numerical value of the free energy decreases, that is to say the oxides become less stable as the temperature increases and tend to decompose.

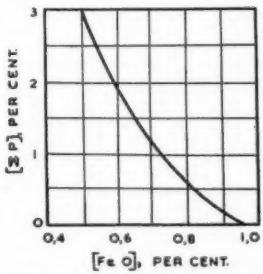


FIG. 5.—*Equilibrium between phosphorus and ferrous oxide* (*Herty*).

This diagram refers in each case to the combination of the various elements with gaseous oxygen; then for each case, only that element and oxygen are present.

If a mixture of pure phosphorus and pure carbon is heated in the presence of oxygen, then it will be appreciated that the phosphorus will be oxidized preferentially until a temperature of about 770 deg. C. is reached. Beyond this temperature, the free-energy change favours the oxidation of carbon to carbon monoxide and the oxidation of phosphorus gives way to that of carbon. In a steel containing phosphorus and carbon, this does not take place until the steel is molten. However, in the molten state, the same order of these two oxidation reactions and the other reactions persists, and it is quite evident that for efficient phosphorus removal the reaction must occur at a temperature at which oxidation of phosphorus will take place preferentially to that of carbon.

Thus in the basic-Bessemer process in which the metal is at all times at a temperature in excess of 1,450 deg. C., which favours carbon removal, the phosphorus is not oxidized until the so-called "after-blow" period (Fig. 4). This is because the carbon content is reduced to such a value that the available oxygen becomes partitioned between a small amount of carbon and a much larger amount of phosphorus.

The phosphorus in steel is combined with the iron to form iron phosphide—Fe_3P. The oxygen necessary for the formation of phosphorus pentoxide is supplied by the ferrous oxide, FeO, according to the reaction:—

$$8FeO + 2Fe_3P = (FeO)_3P_2O_5 + 11Fe \quad \ldots \quad (5)$$

$$\text{For which } K = \left(\frac{((FeO)_3P_2O_5)}{[P]^2\,(FeO)^8}\right) \quad \ldots\ldots \quad (6)$$

As stated earlier, the [FeO] in the metal depends on the (FeO) in the slag, *i.e.*, there is a partition of FeO between slag and metal, so that for a given slag (FeO), the metal [FeO] can be deduced, the partition coefficient being:

$$L_F = \frac{[FeO]}{(FeO)} = 0.0095 \quad \ldots\ldots\ldots \quad (7)$$

These relationships can be expressed in two forms —Fig. 5, which shows the phosphorus content of the metal compared to the ferrous oxide content of the slag, and Fig. 6, which shows the phosphorus of the metal compared to the phosphorus pentoxide of the slag. These relationships, based on work done by Herty,[9] using only iron, iron oxide, phosphorus and phosphorus pentoxide, clearly indicate the rôle of iron oxide in phosphorus removal.

The oxidation of phosphorus alone does not, however, complete the removal action. The P_2O_5 formed requires a "carrier" and this is provided by the calcium oxide, CaO, of the slag. The precise nature of the lime phosphate formed at steelmaking temperatures has not been definitely determined, but it is believed to be tetra-calcium phosphate, $4CaO \cdot P_2O_5$, tricalcium phosphate, $3CaO \cdot P_2O_5$, or both. This means that the *removal* of phosphorus is not carried out without the presence of a basic slag. In order that this slag should be basic, the lime content must be in excess of that required to neutralize the acid constituents, particularly the

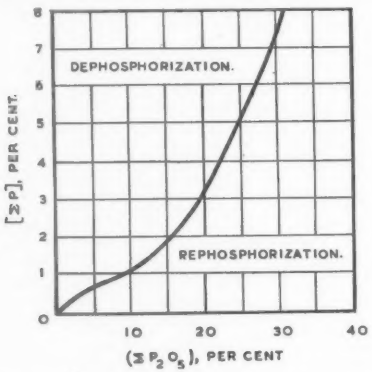


FIG. 6.—*Equilibrium between phosphorus in iron and phosphorus pentoxide in slag (Herty).*

silica, SiO_2, with which the CaO combines preferentially to form di-calcium silicate, $2CaO \cdot SiO_2$.

Phosphorus removal depends not on the total amount of lime present but on the presence of free or uncombined lime. Di-calcium silicate, $2CaO \cdot SiO_2$, corresponds to a lime : silica ratio of 1.87 so that this is the minimum value of the ratio of $CaO : SiO_2$ before any of the lime can be considered to be in the uncombined or free state, and therefore able to combine with phosphorus pentoxide, and so fix the phosphorus in the slag. The effect of the lime : silica ratio and ferrous oxide on phosphorus distribution between slag and metal is shown in Fig. 7.

Consideration of these factors enables a method for the elimination of phosphorus, particularly when higher than normal, to be deduced, *viz.*: immediately upon completion of melting, when the bath temperature is approaching 1,500 deg. C. maximum, a short injection of oxygen at a lower rate than that required for carbon elimination will serve to oxidize the bulk of the phosphorus to phosphorus pentoxide. If suitable steps have been taken previously to ensure the presence of free lime in the slag, then the P_2O_5 will be carried into the slag in combination with this lime. Since the oxidation is exothermic, the rate of the reaction will tend to slow down as it proceeds although the phosphorus is being carried away from the sphere of oxidation. Despite the limitations imposed by this consideration, initial phosphorus contents of 0.20 per cent. have been reduced to 0.02 per cent. in this way. Time and expense can be saved in removing the phosphorus in one slag and the practice of employing multiple slags is not the solution to the problem of high phosphorus. The rate of phosphorus removal by this method is tedious and inefficient for the operation is usually carried out at a temperature which is too high for efficient phosphorus oxidation in the presence of carbon—too high, because the temperature is required in order to flux each new slag. In addition, more moisture—and therefore hydrogen—is introduced with each new slag. It may happen that a melt may have been processed to a temperature not conducive to phosphorus removal without attaining the phosphorus level required. The remedy to that is to follow the example employed in the operation of the basic-Bessemer converter (Fig. 4), that is, to blow out the carbon and eliminate phosphorus in the afterblow. This again is expensive, since the carbon, manganese and silicon have to be made up to specification by pig-iron and ferro-alloy additions, but the method is more economic in most cases than multiple slagging and most assuredly more certain of success.

Calcium Fluoride

Fluorspar is a useful agent in the fluxing of steelmaking slags. The immediate effect of its addition is a physical one, since it reduces the viscosity of the slag. It thus enables the slag to carry more lime at a given temperature, that is, fluorspar enables a more-basic slag to be carried. There is also a result advantageous chemically which derives from using fluorspar. It will be seen from equation (5) that any increase in the concentration of FeO will further promote the formation of $(FeO)_3 P_2O_5$. This is in fact what fluorspar does. The effective concentration of FeO is determined by its activity, αFeO, and by increasing the activity of the FeO, fluorspar increases the effective concentration of the FeO. This effect is clearly shown in Fig. 8. The effect of fluorspar is thus twofold, increasing both the physical and chemical potentialities of a basic slag in the removal of phosphorus.

In the later reducing stage of the melt, at the temperatures reached in the white slag, fluorspar reacts with silica giving a volatile compound, silicon tetrafluoride. Nevertheless, it is generally recognized that the assistance given by the addition of 'spar in the desulphurization of the bath at this stage is due to the additional fluidity conveyed to the slag rather than by the reaction quoted earlier.

Oxidizing-slag Composition

The exact composition of the oxidizing slag will depend on the carbon and phosphorus content of the charge and the extent to which the phosphorus has to be reduced. In a slag bulk of from 2 to 5 per cent. of the metal weight, the lime:silica ratio should be from two to three; the total ferrous-oxide content should be between 5 and 25 per cent. —being lower with increased initial carbon content and greater when the initial carbon content is lower; and the calcium fluoride should be between 2 and 8 per cent.—increasing with increase in lime ratio and decreasing with increased (FeO) content. It should be noted that ferrous oxide (FeO) also fluxes CaO/SiO_2 slags, and that with a high (FeO) content the need for fluorspar either as a flux or to increase the activity of the ferrous oxide does not apply.

"Boil"—Carbon Removal

The "boil" which depends upon the carbon/oxygen reaction is the crux of the steelmaking process. It may be influenced by other competing oxidizing reactions, because all the oxidizible constituents, Si, Mn, and other metalloids, are involved. With increase of temperature, some of these reactions may reach equilibrium and even become reversed. Thus, in acid practice, there arises the throw back of silicon into the bath by the reversal of the Si/FeO reaction.* In basic practice, silicon is rapidly reduced to a very low concentration during the melting period, and is only of interest at the time of deoxidation. Mn introduces considerations that are best discussed after the main C/FeO reaction.

The rate of carbon drop, when divorced from the effects of ore or oxygen addition depends upon the following factors: slag composition, its volume and conditions (and thus its homogeneity), the depth of the metal bath, the temperature and the character of the furnace bottom. Hence, shallow baths, low slag-volume and slag fluidity all promote rapid elimination of carbon. The carbon in the bath can be determined fairly readily. Thus, there is fortunately at hand a ready means of control, for not only is the carbon drop the prime criterion of the character of the oxidation process. but the slope of the C/time curve is the critical index of the rate of reaction, and thus evaluates also the effects of the less-tangible factors, such as diffusion and mechanical action in the bath.

In the electric-arc furnace, the oxygen is supplied from either the addition of iron ore, or, as now almost standard practice, directly by injection of gaseous oxygen. The actual reaction of the carbon boil is between [C] and [FeO], the [FeO] being formed from the action of the gaseous oxygen, the equations being:—

$$Fe + \tfrac{1}{2}O_2 \rightarrow FeO, \text{ an exothermic reaction} \quad (8)$$

$$FeO + C \rightleftharpoons CO + Fe, \text{ endothermic reaction} \quad (9)$$

The heat-exchange is such that the overall effect is a gain of 310 B.T.U. per ton for each 0.01 per cent. carbon removed. The oxidation of the Si, Mn, and P is also exothermic. Consideration of the Ellingham diagram (Fig. 3) indicates that, as the temperature increases, the stability of carbon monoxide also increases whilst the stability of the oxides of the above elements decreases. According to the Le Chatelier principle, the effect arising from any increase in temperature due to this thermal gain should be to increase the endothermic reaction involving

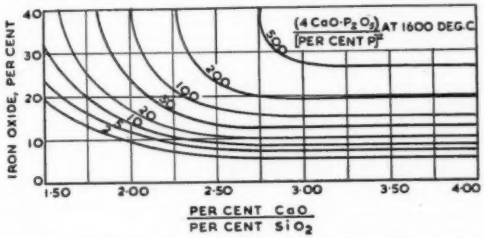


FIG. 7.—*Effect of ferrous oxide and the lime:silica ratio on the distribution of tetra-calcium phosphate in slag and phosphorus in metal. (Winkler & Chipman).*

carbon (equation (9)). In practice, the law of mass action determines the final effect, since the concentration of the principal reactant, carbon, is continually decreasing.

Manganese Reactions

In order to throw light on the reactions of manganese in the bath, recourse has to be made to the exclusive investigations that have been made in the basic open-hearth process to the reaction between the MnO in the slag and the FeO dissolved in the metal. Thus from the reaction:—

$$[FeO] + [Mn] \rightleftharpoons (MnO) + [Fe] \quad \ldots\ldots \quad (10)$$

the equilibrium constant is:—

$$K' = \frac{(MnO)}{[FeO]\,[Mn]} \quad \ldots\ldots\ldots\ldots \quad (11)$$

Darken and Larson[10] expressed the manganese equilibrium as:—

$$[\text{Per cent. Mn}] = \frac{(MnO)}{(FeO)} \times \frac{1}{K'} \quad \ldots\ldots \quad (12)$$

using Körber's[11] value for the equilibrium constant, K', where:—

$$\log K' = \frac{5{,}960}{T} - 2.877 \quad \ldots\ldots \quad (13)$$

and the (FeO) value is the total iron in slag computed as FeO.

Thus, the manganese in the metal could be computed from actual open-hearth data, and the only practicable conclusion is that the higher the temperature, the higher the manganese recovery in the metal. That temperature has a strong influence on manganese distribution has been well recognized; it is known that the residual manganese frequently increases towards the end of a melt in spite of the lowered carbon and rising ferrous-oxide in the slag. The distribution of manganese between slag and

* This is referred to later (equations (17) and (18)). It is noteworthy that the equilibria for the silicon and manganese reactions under a silica-saturated slag have been derived by Körber and Oelsen,[18] from which the relationships applying in the acid hearth of an electric furnace at the completion of the carbon boil can be derived.

steel is so sensitive that the relationship has been used to estimate bath temperatures. It is strongly probable that the laws applying in these reactions to basic open-hearth melting apply also to the basic electric steel melting practice. The circumstance in the electric process, whereby the oxidation period is followed by the reduction period in which the iron and manganese are removed from the slag by the addition of reducing agents, renders latitude in the use of readily-oxidizable alloy additions.

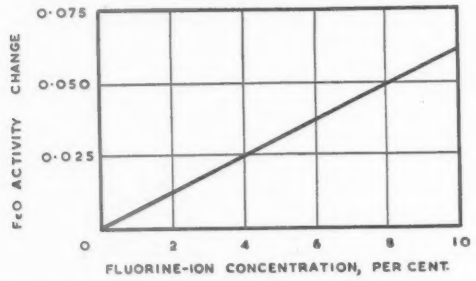


FIG. 8.—*Effect on fluorspar (in terms of ion concentration of fluorine) on the activity of ferrous oxide.*

Influence of the Carbon Boil on Degassing

Reverting to the character of the carbon boil, from consideration of the Vacher-Hamilton isotherm, Fig. 2, the necessity of increasing the [FeO] content of the metal in order to decrease the carbon content particularly at low-carbon concentrations is readily seen. A satisfactory expression of the rate of carbon removal in terms of the variables concerned has not yet been produced, but there can be no doubt that such an expression is likely to be of the type:—

$$-\frac{dC}{dt} = f[C] - K \quad \ldots\ldots\ldots \quad (14)$$

where K is also a variable dependent on the composition of the bath.

Use of Oxygen Injection

In oxygen injection, for efficient carbon-removal the oxygen input must be adjusted to a rate determined principally by the initial carbon level. As indicated in Fig. 9, the oxygen input has to be increased as the initial carbon level decreases, in order to obtain carbon removal at a satisfactory rate.

The use of oxygen gives a very vigorous boil. Barraclough[12] has emphasized the benefit of a vigorous boil as a means of expelling hydrogen from the bath. Darken[13] has postulated nitrogen and hydrogen removal rates in terms of the carbon removal rates by the expressions:—

$$-\frac{d[N]}{dt} = -\frac{28}{12}\left(\frac{[N]}{0.04}\right)^2 \cdot \frac{d[C]}{dt} \quad \ldots\ldots \quad (15)$$

and

$$\frac{d[H]}{dt} = -\frac{2}{12}\left(\frac{[H]}{0.0027}\right)^2 \cdot \frac{d[C]}{dt} \quad \ldots\ldots \quad (16)$$

From these relationships, it is clear that the rates of nitrogen and hydrogen removal are directly proportional to the rate of carbon removal. Since a maximum carbon-removal rate and most vigorous boil is attained by means of oxygen injection, there is this beneficial gas-removal in addition to any other economic advantages associated with the use of gaseous oxygen. A vigorous boil is more easily attained with a high initial or as-melted carbon content. Accordingly, for efficient gas removal, it is essential to have as high a carbon as possible in the bath as-melted.

These two equations of Darken apply only in circumstances where carbon is being removed and no additional nitrogen or hydrogen is being brought into the reaction zone. In the case, however, of Bessemer or Tropenas practice, where carbon is being removed by air blast, nitrogen and hydrogen (as water-vapour) in excess of that present prior to the boil, are introduced, so that the gas-removal rate is diminished and indeed reversed as the carbon removal proceeds.

In the basic electric-arc practice, the end of the oxidation period comes with the removal of the slag. At this stage, in order to prevent reversion of the phosphorus in the oxidation slag into the metal, it is essential to remove as much of the slag as practicable, and yet without over-exposing the metal to atmospheric oxidation on its surface. If the phosphorus in the charge was originally low and valuable elements such as chromium are to be recovered from the oxidation slag, this slag is then submitted to the reduction treatment.

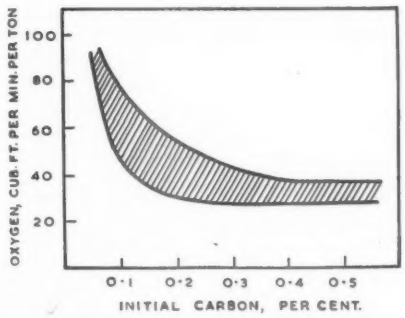


FIG. 9.—*Specific oxygen input (cub. ft. per min. per ton) required to initiate carbon removed at various initial-carbon levels.*

Reducing Period

The chief advantage of the arc furnace as a steel-making appliance lies in the fact that the energy supply is readily conveyed to the slag, both by conduction from the arcs and by re-radiation from the furnace brickwork. Since the input of heat is readily variable by the control of the arc, temperature may be rapidly built up and readily controlled. The highest desirable temperatures are attainable and this circumstance, together with the fact that the furnace atmosphere is—within limits—also

controllable, makes possible the use of reactions that can only be carried out at high temperatures.

Accordingly, by the building up of a new lime-slag and treating this slag with reducing agents the final stage of refining is reached. It may be necessary to stop the bath before the final refining if the carbon or other oxidizable elements have reached the required limit of composition. The usual deoxidants are used, ferro-silicon, ferro-manganese or calcium-silico-manganese, according as to how the composition may require adjustment. Such an addition, bringing the bath nearly to its final composition, admits of the analysis of a final bath sample before tapping.

Deoxidation in the basic electric-arc process is to be regarded as a diffusion process, the dissolved FeO being removed from the steel by reducing the FeO in the slag to the lowest practicable value by treatment of the slag with coke or graphite or—occasionally—powdered ferro-silicon on the surface. The silicon reduction is governed by the reaction[14]:—

$$K_{Si} = \frac{(FeO)^2[Si]}{(SiO_2)} \quad \ldots\ldots\ldots\ldots \quad (17)$$

The temperature function of this equilibrium constant is:

$$\log K_{Si} = -\frac{11106}{T} + 4.50; \quad .. \quad (18)$$

between the range of temperature 1,600 to 1,650 deg. C., it falls in the range 0.037 to 0.053. per cent. During the deoxidation, as the FeO is removed from the slag and the diffusion phenomena enable the partition equilibrium to be approached, the relationship governing the partition is given[15] by:—

$$L_{FeO} = \frac{[FeO]}{(FeO)} = 5.88 \times 10^{-5}.\ t \text{ deg. C.} - 0{\cdot}0793 \quad \ldots\ldots\ldots \quad (19)$$

Thus the [FeO] in the metal can be derived, given the pertinent data. Normally, the metal is completely "killed" when it has absorbed 0.2 per cent. silicon. It is possible also by means of a decarburizing slag to free the metal almost completely from dissolved ferrous oxide.

The advantage of reducing the dissolved FeO by this means rather than by introducing the additions into the metal bath lies in the fact that the products of the reactions:—

$$FeO + C \rightarrow Fe + CO \quad \ldots\ldots\ldots \quad (20)$$

$$2FeO + Si \rightarrow Fe + SiO_2 \quad \ldots\ldots \quad (21)$$

are either confined to the slag or are volatile. Further, the deoxidizers are insoluble in the slag and act in an undiluted condition in the slag oxides.

The formation of calcium carbide in the slag serves as a sensitive indicator of the reduction process, since calcium carbide is itself a reducing agent that would be destroyed by metallic oxides, thus:—

$$CaC_2 + 3FeO \rightarrow CO + CaO + 3Fe \quad (22)$$

Perrin[16] showed the value of agitation in hastening the operation of the partition equilibrium.

Desulphurization

Desulphurization of the reducing slag proceeds by way of lime. It can be expedited by alternating strong reducing conditions with atmospheric oxidation, whereby calcium sulphide is oxidized to lime and sulphide dioxide, and the sulphur accordingly rendered volatile. In the reducing slag, some doubt exists as to the exact mechanism of reactions between sulphur, lime and calcium carbide (and calcium fluoride, if present). The high values of the free energy of formation of the calcium and magnesium sulphides suggest that the direct reaction between the base and sulphur is the primary factor. It is well known—for the reaction to proceed—that the basicity of the slag must be high. The relationship of the sulphur partition between metal and slag in so far as it is influenced by the lime, ferrous oxide and silica content of the slag and the temperature is shown in Fig. 10. From this diagram, it is apparent that low ferrous-oxide and low silica in the slag is essential for good desulphurization. The well-known property of calcium carbide as a desulphurizing agent may be the indirect effect of the reduction of ferrous oxide by the action of calcium carbide, thus:—

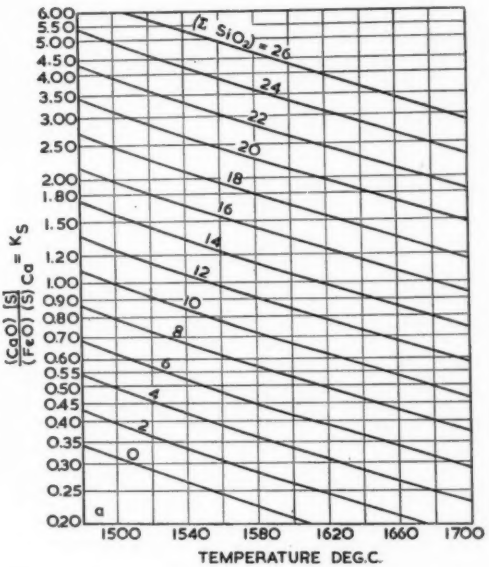


FIG. 10.—*Equilibrium constant for desulphurization with lime with varying silica content and temperature of the slag (Schenck).*

$$CaC_2 + 3FeO \rightarrow CaO + 3Fe + 2CO \; .. \quad (23)$$

For this reaction:

$$\Delta F = -2.540 - 56.55T. \quad .. \quad (24)$$

It is endothermic and therefore favoured by increased temperature. As well as increasing the activity of ferrous oxide (Fig. 8), the action of calcium fluoride is also physical, in producing

fluidity and the mobility necessary to accelerate the lime reaction. CaF_2 at the high temperature of the reducing slag reacts with SiO_2 to give silicon tetrafluoride, thus:—

$$2CaF_2 + SiO_2 \rightarrow 2CaO + SiF_4 \quad .... \quad (25)$$

The lime produced is probably in a nascent condition and possibly more active as a desulphurizing agent. This reaction can be readily observed in the electric furnace from analyses taken at successive intervals of time. The influence of ferrous oxide on the sulphur partition in reducing slags in the electric furnace is shown in Fig. 11. This confirms the validity of Fig. 10, which was developed from a study of basic open-hearth slag-reactions.

In basic electric-arc furnaces, dolomite hearths are in fairly general use, so that magnesia, MgO

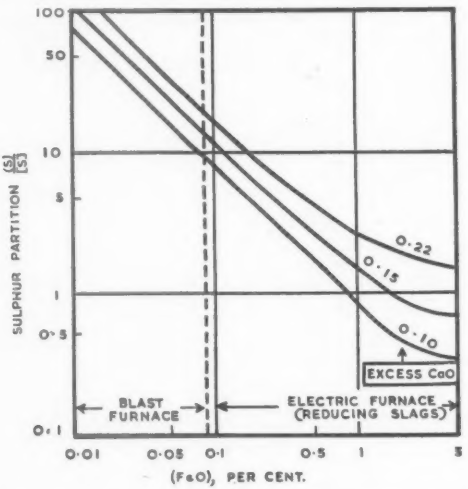


FIG. 11.—*Sulphur distribution as a function of the ferrous oxide of the slag and excess lime (in mol fractions) in the slag (Rocca, Grant & Chipman).*

is always present in basic arc-furnace slags. Since magnesium is used in a different process as a desulphurizing agent, the impression might be created that magnesia should be a desulphurizing agent, thus:—

$$(MgO) + FeS \rightleftharpoons (MgS) + FeO \quad .. \quad (26)$$

Comparing the equilibrium constant of this reaction with that of the lime reaction:—

$$\text{gives } (CaO) + FeS \rightleftharpoons (CaS) + FeO \quad .... \quad (27)$$

$$K_{CaO} = 0{\cdot}04 \text{ at } 1{,}700 \text{ deg. C.} \quad .... \quad (28)$$

$$\text{and } K_{MgO} = 1 \times 10^{-4} \text{ at } 1{,}700 \text{ deg. C.} \quad (29)$$

Even allowing for discrepencies in the calculated activities of the reactants, it is safe to state that CaO has a desulphurizing power of about 1,000 times that of MgO[17].

Desulphurization of metal having slag (FeO) in excess of the 2 per cent. maximum normal in basic arc-furnace practice is carried out in the presence of excess base by the mechanism of partition of iron sulphide and manganese sulphide, viz:—

$$L_{FeS} = \frac{(FeS)}{[FeS]} \quad ..... \quad (30)$$

and

$$L_{MnS} = \frac{(MnS)}{[MnS]} \quad ..... \quad (31)$$

The value of L_{FeS} has been established by Bardenhauer and Geller[18] as 3.6 and that of L_{MnS} by McCance [19] as 300. In normal basic arc-furnace practice, these reactions could take place since increasing temperature increases the oxygen content of the metal. To a great extent this effect is offset by the ability of the slag to carry more lime at the increased temperature.

Initial Deoxidation

After the reducing slag has completed its function of removing sulphur, all that remains to complete the processing of the metal is the neutralizing of the inherent gases, combined and uncombined, to prevent any adverse effect in the solidified castings. Efficient deoxidation is not merely the combination of oxygen with a deoxidant; not only should the deoxidant have a high affinity for oxygen, (Fig.12), but the products of deoxidation must be of such a physical character as to be able to pass readily into the slag. In order to do this, the deoxidation product must be liquid in the steel, immiscible and have such a size, ability to coalesce, and density that it will pass readily into the slag. Consideration of the liquidus surface of the $FeO/SiO_2/MnO$ system [20] (Fig. 13), indicates that binary constituents of FeO/MnO and FeO/SiO_2 within certain ranges of composition have extremely high melting points, indeed, silica-rich products of deoxidation are solid at steelmaking temperatures. In order to ensure fluidity, deoxidation products should be of such composition as to lie in the low-temperature liquidus-trough lying between the compounds, $2MnO.SiO_2$ and $2FeO.SiO_2$ It is quite apparant from these considerations that a combination of silicon and manganese is superior both in deoxidation power and in the fluidity of the product than either deoxidant used individually. A fluid product in the $FeO/SiO_2/MnO$ system is obviously more readily attained by an addition of manganese followed by silicon rather than silicon followed by manganese. Nowadays, combinations of manganese and silicon are obtainable which fulfil this purpose of the ready production of fluid, immiscible oxides. It has been claimed that the use of Mn/Si alloys for deoxidation results in the production of larger globules of deoxidation products which by virtue of their size more readily coalesce with other globules and pass more easily into the slag. Low-temperature liquidus-troughs also appear in the $CaO/SiO_2/FeO$ and $CaO/SiO_2/MnO$ systems and the presence of calcium in the deoxidant is advantageous for this reason. It should be noted that deoxidation by means of ferro-alloys to a near final state should be carried out in the furnace rather than in the ladle since the passage of the deoxidation products into the slag will be easier through the shallow bath of metal in the ladle.

A fact which is almost completely overlooked is the very rapid increase in oxygen solubility in the temperature range 1500 to 1700 deg. C. (Fig.14). It follows from this that deoxidation should be preceded by a temperature check in order to ensure adequate deoxidation or prevent waste of costly ferro-alloys.

Final Deoxidation

In the steel-castings industry, aluminium is almost universally used as a final deoxidant. The products of deoxidation are alumina Al_2O_3 and hercynite $FeO.Al_2O_3$ both of which are solid at steelmaking temperatures. As can be seen from reference to Fig. 12, the deoxidation effect of aluminium in the presence of silicon and manganese is much more powerful than when used alone. The amount of aluminium addition has been shown by Sims and Dahle[21] to be extremely critical because of its effect on the physical properties of the steel by affecting the type of inclusion obtained. In their experiments, absence of aluminium gave a globular Type-1 inclusion due to the presence of oxygen; a small addition of aluminium, 0.04 to 0.05 per cent. resulted in a eutectic of MnS and iron forming round the grain boundaries (Type-II inclusion) characterized by very low ductility in the steel. A further addition of aluminium, 0.10 per cent., and more, resulted in the larger, more scattered and irregularly-shaped Type-III inclusion, with a restoration of ductility. This larger type of inclusion was attributed to the excess of aluminium, forming aluminium sulphide Al_2S_3, which is less soluble than MnS or FeS, and is precipitated at a higher temperature, causing the inclusions to be large and scattered rather than

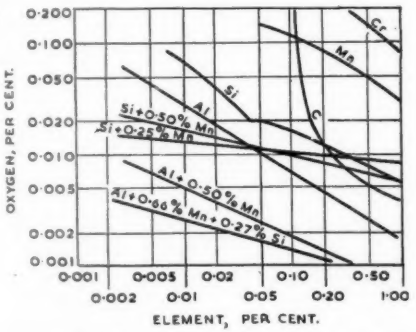


FIG. 12.—*Equilibrium between deoxidizing elements individually (and in combinations) and oxygen at* 1,600 *deg. C. on a logarithmic diagram (Hilty).*

small and existing in the form of grain-boundary films. The strong deoxidizers give Type-III inclusions, while the weaker ones give Type I, *viz.*:—

Inclusion.	Deoxidizer.
Type I ..	Silicon, manganese, vanadium.
Type II ..	Aluminium, titanium, zirconium, magnesium and boron.
Type III ..	Aluminium, zirconium and magnesium.

Sims[22] has also stated that an aluminium concentration of 0.003 per cent. or a titanium concentration of 0.02 per cent., though giving Type-I inclusions, is sufficient to prevent pinhole porosity. The effect of rate of cooling on inclusion type was studied by Lillieqvist,[23] who found that Type-III inclusions resulted from the addition of 2½ lb. of aluminium per ton of steel when cast in a sand mould, but that Type-II inclusions resulted from a quicker rate of cooling. This adverse effect on rapidly-cooled castings was eliminated by a 3-lb. per

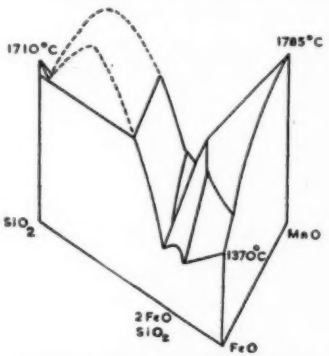


FIG. 13.—*Ternary system $SiO_2/MnO/FeO$ (Hay, White & MacIntosh).*

ton addition of calcium/silico/manganese together with the aluminium.

Degassing

In addition to being picked up from the slag-making materials, it may also happen that nitrogen is continually picked up from the furnace atmosphere by the reaction of the CaO of the slag and the carbon of the electrodes according to the equation:—

$$CaO + 2C + N_2 \rightarrow CaCN_2 + CO \quad .... \quad (32)$$

or by the reaction of nitrogen with calcium carbide:—

$$CaC_2 + N_2 \rightarrow CaCN_2 + C \quad .... \quad (33)$$

The calcium cyanamide so formed would then dissociate, releasing N_2 into the slag and metal.

Mention has been made earlier of "rock candy" fracture. This happily is a rare type of failure, but one which must be guarded against. It has been shown[4] that in plain carbon steel 0.004 per cent., and in low-alloy steel 0.002 per cent., of nitrogen as aluminium nitride are the critical concentrations above which "rock candy" fracture can occur. This nitrogen can be fixed by the addition of zirconium or by the addition of titanium. Particularly in the use of the latter, aluminium is still necessary as a deoxidant in order to prevent Type-II sulphide inclusions. The susceptibility of a steel to intergranular fracture even with aluminium and nitrogen present can be controlled by suitable cooling rates and even when aluminium nitride is present in the casting it can be eliminated by a suitable heat-treatment.[4]

Hydrogen is, of course, responsible for casting porosity in varying degrees, and adversely affects the ductility of the steel. While the amounts will vary according to ladle and sand practice, the amount of hydrogen in the bath metal which will lead to porosity is about 5 ml. per 100 gm. and that which gives a rising melt is about 9 ml. per 100 gm. for plain carbon steels. These amounts will increase with alloy content. In a 0.1 per cent. carbon steel the reduction of area of a test-bar falls from 70 to 10 per cent. as the hydrogen increases from 1 ml. per 100 gm. to 7 ml. per 100 gm. Hydrogen cannot be fixed in the steel as innocuous compounds in

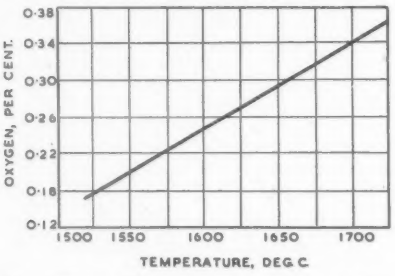


FIG. 14.—*Effect of temperature on the solubility of oxygen in iron* (*Ascik, Journal of Metals* 1953 **5** (8) 986).

the same way as that in which nitrogen can be controlled. Claims have been made that polytetrafluoroethylene, used as a ladle addition is effective in removing small quantities of hydrogen from steel, probably as hydrogen fluoride, but quantitative data on this expedient have not yet been published.

Conclusion

From a knowledge of thermochemical and thermodynamic considerations, the possibility and probability of a particular chemical reaction following a particular course in steelmelting phenomena can be deduced, and the conditions of the reactants, whether in the hearth, metal, slag or atmosphere, requisite to give a desired result can in many important cases likewise be determined simply by the correct application of predetermined data. These principles are based on classical theory, but it is only in comparatively recent years that much of the necessary data requisite to the useful application of the principles have been determined with sufficient accuracy to make them serviceable at the high temperatures involved in steelmaking. Physical chemistry in its various aspects, properly applied, has accordingly a great deal to offer the practical steelmaker in his constant effort to improve the quality of the product of his art.

Acknowledgment

This Paper is based on a review of the literature on the physical chemistry of steelmaking for castings, carried out by the British Steel Castings Research Association, whose Council has agreed to its publication.

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APPENDIX

List of Symbols Used

C_p = Heat capacity in heat units per mol.
F_t = Free energy at temperature t° in heat units.
$F°$ = Free energy in standard state in heat units, i.e. at one atmospheric pressure in the case of gases and for one mol in the case of solids.
ΔF = Change in free energy in heat units.
H_t = Heat of reaction at temperature t° in heat units; when negative heat is evolved.
$H°$ = Heat of reaction in standard state in heat units.
ΔH = Change in heat of reaction in heat units.
k = velocity constant for a reaction.
K = equilibrium constant for a reaction.
p = Partial pressure of a gas phase, e.g., pCO is the partial pressure of carbon monoxide and denotes its concentration.
R = Universal constant, often called the gas constant, in units of energy per degree per mol.
S = Entropy in heat units (per degree per mol. of the substance).
$S°$ = Entropy in heat units for standard state.
ΔS = Change in entropy.
t = Temperature in degrees Centigrade or Fahrenheit.
T = Temperature in degrees Centigrade absolute (degrees Kelvin).
ΔT = Change in temperature in degrees Kelvin.

Explanatory Notes

The following brief explanations will serve to clarify some of the more technical points discussed in the Paper :—

The occurrence of a chemical reaction is always accompanied by the absorption or liberation of a certain amount of energy. The heat evolved may be taken up by the substance itself, in which case its heat capacity must be defined in terms of temperature; the heat capacity of a substance usually increases with increasing temperature. A convenient way of recording the data on each substance is by use of an algebraic equation expressing its molar heat-capacity in terms of absolute temperature thus :—

$$C_p = a + bT - cT^{-2} \quad \ldots\ldots \quad (34)$$

a, b and c being constants usually available in the reference books.

Heat of Reaction

A heat of reaction is usually determined experimentally by a calorimetric method. The heat of formation of a compound is the heat absorbed (ΔH)

when one mol (molecular wt. in grams or lb.) is formed at constant pressure from its elements. When heat is formed in a reaction accordingly ΔH is negative. In steelmaking, the heats of reaction are required to be known at high temperatures, and these can be calculated from heats of reaction determined at any other temperature using the relationship

$$\Delta H_2 = \Delta H_1 + \Delta Cp \,.\, dT \quad \ldots\ (35)$$

where ΔH_2 is the heat of reaction at temperature T_2 and ΔH_1 is the heat of reaction at temperature T_1, using the heat capacity Cp referred to in the previous paragraph.

Free Energy, Bound Energy and Entropy

Molecular motion becomes more rapid with increasing temperature and the bound—or thermal—energy of the substance increases. Temperature is one of the parameters of this thermal energy, the other is called entropy, S. The quantity, S, has a characteristic value for each substance and is measured in heat units (calories or B.T.U.) per degree per mol. of the substance.

When the bound energy is subtracted from the total energy, the remainder is called the free energy. Absolute values of the total energy are not known and it is only the changes of energy that are of interest. Thus the free energy, F, is given by the expression :—

$$F = H - TS \quad \ldots\ (36)$$

where H = total energy and T the absolute temperature.

In steelmaking reactions the only tangible values are those which are measured either as heat or work, the energy either being evolved or absorbed in chemical action. Accordingly, since only changes in energy are involved, the pertinent equation is written thus:—

$$\Delta F = \Delta H - T\Delta S \quad \ldots\ (37)$$

where the symbol Δ signifies a change in value.

This quantity ΔF, the free-energy change, signifies the driving force of the reaction. When the free energy, so defined, of a reaction in one direction is negative then the reaction will take place in that direction. The greater the numerical value of this quantity the greater the driving force of the reaction.

Equilibrium Constants

The proof of the law of mass action is comparatively simple, and depends upon the reasonable assumption that the rate of chemical change is proportional to the number of collisions between the reacting molecules, which in the appropriate solutions is proportional to the respective concentrations. Accordingly the rate of reaction depends upon the product of the concentrations. Taking the familiar reaction of manganese and ferrous oxide:

$$[FeO] + [Mn] \rightleftharpoons (MnO) + [Fe] \quad \ldots\ (38)$$

which is reversible, the velocity of the reaction from left to right depends upon the product of the concentrations of ferrous oxide and manganese. Inversely, the opposite reaction velocity depends upon the concentrations of manganese oxide and iron. At equilibrium, the rates just balance; accordingly:—

$$k_1\,[FeO] \times [Mn = k_2\,(MnO)\,[Fe] \quad (39)$$

$$\frac{[FeO]\,[Mn]}{(MnO)\,[Fe]} = \frac{k_2}{k_1} = K \text{ (the equilibrium constant)} \quad \ldots\ (40)$$

In a bath of molten steel, the active mass of the [Fe] is regarded as constant and equal to unity. The reaction continues until its driving force has been diminished and that of the reverse reaction built up so that the two tendencies balance. Thus the driving force is the free energy of the reaction, and the equilibrium state is reached when the free energies of the products add up to the same as the free energies of the reactants.

The influence of temperature on the displacement of the equilibrium is expressed by the well known Van't Hoff equation:

$$\frac{d\,(\log_e K)}{dT} = -\frac{\Delta F}{RT^2} \quad \ldots\ (41)$$

meaning that the rate of change of the logarithm of the equilibrium constant with temperature is equal to the heat evolved in the complete reaction divided by twice the square of the absolute temperature at which the change takes place (R may be taken to have the approximate value of two). By integration of the above equation, the simple relationship is arrived at:—

$$\Delta F = -RT \log_e K = -4{\cdot}575T.\ \log K. \quad (42)$$

which enables free energies to be derived from equilibrium constants and *vice versa*.

For comparing equilibrium constants at two temperatures:—

$$\log K_2 - \log K_1 = -\frac{\Delta F}{4{\cdot}575}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \quad (43)$$

T always being the absolute temperature (degrees Kelvin). If at a given temperature the equilibrium constants for two or more reactions are known, they may be used to calculate the equilibrium constant at the same temperature for a reaction at which the reacting substances are present, in part, in the originals.

Taking the following three reactions:— (i) $CO + H_2O \rightleftharpoons CO_2 + H_2$; (ii) $FeO + CO \rightleftharpoons Fe + CO_2$, and (iii) $FeO + H_2 \rightleftharpoons Fe + H_2O$, the first is the well known water-gas reaction, of which the equilibrium constants are known with accuracy up to temperatures of 1,800 deg. C. The data relating to the second reaction have also been carefully correlated and established to 1,550 deg. C. by H. Schenck.* Since reliable evidence is lacking in regard to (iii), particularly in the temperature range at which fusion occurs, the data can readily be obtained from the data relating to reactions (i) and (ii), thus :—

$$K_1 = \frac{p\mathrm{CO}\,.\,p\mathrm{H_2O}}{p\mathrm{CO_2}\,.\,p\mathrm{H_2}}$$

$$K_2 = \frac{[FeO]\,.\,p\mathrm{CO}}{[Fe]\,.\,p\mathrm{CO_2}}$$

$$K_3 = \frac{[FeO]\,.\,p\mathrm{H_2}}{[Fe]\,.\,p\mathrm{H_2O}}$$

whence $K_3 = \frac{K_2}{K_1}$.

* H. Schenck, Physical Chemistry of Steelmaking (1945), p. 140.

At 1,602 deg. C, $K_3 = \frac{4.02}{4.11} = 0.95$.

In the case, however, of solutions of ferrous oxide in liquid iron, the equilibrium constant for reaction (ii) is expressed by :—

$$K^1 = \frac{p\text{CO}\,[\text{FeO}]}{p\text{CO}_2} \quad \ldots\ldots \quad (44)$$

Accordingly, information on the concentration of ferrous oxide is required. This requires data relating to the solubility of ferrous oxide in liquid iron, which can be obtained from published data.*

Pursuing the matter further and reverting to the reaction (ii), and considering two further reactions: (iv) $CO_2 \rightleftharpoons CO + \frac{1}{2}O_2$, the dissociation of carbon dioxide, and (v) $FeO \rightleftharpoons Fe + \frac{1}{2}O_2$, the dissociation of ferrous oxide, in the same manner $K_5 = K_2 \times K_4 = 4.02 \times 4.677 \times 10^{-7} = 1.88 \times 10^{-6}$; and this gives the equilibrium constant for the dissociation of ferrous oxide at a temperature of 1,600 deg. C.

Another example of the technique explained in the preceding section relates to the dissociation of steam:—

$$H_2O \rightleftharpoons H_2 + \tfrac{1}{2}O_2 \quad \ldots\ldots\ldots \quad (45)$$

for which $$K = \frac{pH_2 \cdot p\frac{1}{2}O_2}{pH_2O} \quad \ldots\ldots\ldots \quad (46)$$

The values of heat content and entropy for computation of the free energy change using:—

$$\Delta F^\circ = \Delta H^\circ - T\Delta S \quad \ldots\ldots \quad (47)$$

and are known with great accuracy. Some typical values are shown in Table A. Taking the reverse of the first reaction in the Table which gives the dissociation of steam into hydrogen and oxygen, and since:—

$$\Delta F^\circ = -RT \log_e K \quad \ldots\ldots \quad (48)$$

$$\log K = \frac{-\Delta H^\circ_{25}}{4.575T} + \frac{\Delta S^\circ}{4.575} \quad \ldots\ldots \quad (49)$$

using the tabulated values for H° and S°, then:

$$\log K = \frac{-13{,}150}{T} + 3.05 \quad \ldots\ldots \quad (50)$$

whence, at 727 deg. C., log K = − 10.145 and $K = 8.0 \times 10^{-11}$.

A further example deals with the oxidation of molybdenum by the oxides of carbon.
(*a*) $Mo + O_2 \rightarrow MoO_2$, for which $\Delta F^\circ_a = -133{,}600 + 43.07T$ and (*b*) $2CO_2 = 2CO + O_2$, for which $\Delta F^\circ_b = 135{,}100 - 41.50T$. If it is required to ascertain the effect of CO_2 on molybdenum at a temperature of 1,600 deg. C., *i.e.*, 1,873 deg. K., at a total pressure of one atmosphere, the addition of equations (*a*) and (*b*) gives: (*c*) $Mo + 2CO_2 \rightarrow MoO_2 + 2CO$, for which the free-energy change (obtained by addition of $\Delta F^\circ_a + \Delta F^\circ_b$) is, $\Delta F^\circ_c = 1{,}500 - 1.57T$.

However, $\Delta F^\circ_c = -4{,}575T \log K$ so that $-4.575T \log K = 1{,}500 - 1.57T$. At T = 1,873K., K = 0.30; by L.M.A. $K = \frac{p^2CO_2}{p^2CO_2}$

therefore $$\frac{p\text{CO}}{p\text{CO}_2} = 0.55$$

If x is the partial pressure pCO, then $(1 - x)$ is the partial pressure pCO_2, so that $\frac{x}{1-x} = 0.55$, from which $p\text{CO} = 0{\cdot}35$ and $pCO_2 = 0{\cdot}65$. Thus oxidation will take place at a CO_2 pressure of more than 0.65 atmosphere. Or, alternatively, if the atmosphere has a pressure of unity (760 mm. Hg) the CO_2 composition of the atmosphere must reach 65 per cent. before oxidation takes place.

Dissociation Pressure of the Oxides

Since in the dissociation of an oxide gaseous oxygen is formed—the concentration of which can be expressed as a gas pressure—an extension of the technique described allows for the determination of the dissociation pressure of the oxide. The more stable the oxide, the lower is the dissociation pressure, and the larger is the value of ΔF°, or the larger the negative value of ΔF for the formation of the oxide from its elements. Thus the relative stabilities of the oxides of the various metals may be compared by their dissociation pressures at some one temperature, or by the energy required to break them up into their constituent elements.

To illustrate this point, for a few typical oxides in use in steelmaking, the dissociation pressures at 1,000 deg. K. are shown in Table B; metals higher in the list will reduce those lower down. There is thus an index of activity just as the chemical-reaction concentration serves as an index of mass activity.

TABLE A.—*Heat Content and Entropy for Typical Gaseous Reactions at 25 deg. C.*

Reaction.	ΔH cal per mol.	ΔS cal. per mol per deg. K.
$H_2 + \frac{1}{2}O_2 = H_2O$	− 60,180	− 13.93
$H_2 + CO_2 = H_2O + CO$	+ 6,380	+ 6.22
$[C] + CO_2 = 2CO$	+ 38,460	+ 40.35
$CO + \frac{1}{2}O_2 = CO_2$	− 66,560	− 20.15
$H_2 = 2H$	+ 108,300	+ 28.80

TABLE B.—*Dissociation Pressures of Oxides.*

Substance.	Dissociation pressures (pO_2, atmospheres).
CaO	1.6×10^{-28}
Al_2O_3	1.5×10^{-24}
SiO_2	2.0×10^{-18}
MnO	3.1×10^{-17}
CO	3.0×10^{-11}
FeO	3.8×10^{-12}
MoO_2	5.6×10^{-13}
H_2O	8.0×10^{-11}
NiO	1.7×10^{-6}

* F. Körber, *Stahl und Eisen* (1932), **52**, 133-142.

AN INQUIRY has been received by Whitby (Yorks) Rural Council from Metal Containers, Limited, Ellesmere Port (Cheshire), regarding suitable premises in the area for a factory or a site of between 15,000 and 20,000 sq. ft. for the erection of a factory.

THE OIL TANKER Catatumbo has been bought by George Cohen Sons & Company, Limited. The ship, built in Newcastle in 1928, weighs 3,163 tons gross and 1,671 tons net. She is now being towed from Venezuela.

CO_2 Process: Formation and Dissolution Mechanism in Relation to the Silicate Bond

By C. Starr

Discussing the chemical nature of the sand/silicate bond when making foundry moulds and cores, the effects of three groups of metal casting temperatures are described—with CO_2 used as the setting agent. The reasons why breakdown of spent moulds for high- and low-melting-point alloys is good while it is difficult for those of medium melting-point metals (such as copper-base alloys and cast iron) are explained. The writer dismisses the series of additives so far used to improve breakdown as being merely palliative and states the desirable characteristics of an ideal material.

The possibility of utilizing alkaline silicates for the bonding of foundry core-sands has attracted attention from the early twentieth century onwards. There are, indeed, academic references to their possible use for this purpose which date from the late nineteenth century. The main reason for this interest is to be found in the cheapness of silicates, relative to the cost of organic oils. This cost advantage is, however, more than offset by the thermal stability of the various silicate complexes. Since early silicate practice was based upon a mixing/stoving cycle—anticipating the classic oil-sand technique—this lack of thermal sensitivity proved a serious obstacle to the acceptance of silicates by the foundry industry.

New Approach

Interest in the potentialities of silicates in the foundry, which the inherent limitations had caused to lapse, has been revived in recent years by a new concept of technique. This new approach was based upon the reaction between sodium silicate and carbonic acid, which proceeds according to the empirical formula:—

$$Na_2SiO_3 + H_2CO_3 = Na_2CO_3 + SiO_2\,(H_2O)$$

The carbonic acid is generated in contact with the silicate as the result of interaction between gaseous carbon-dioxide and the aqueous base of the silicate solution. Where the silicate solution is intimately admixed with sand, through which the gas is subsequently passed, the reaction proceeds on the surface of the sand grains, the result being a sand mass bonded with silica-gel.

The sensitivity to heat of this silica-gel bond is fairly high, since loss of water causes it to be degraded to the far less cohesive anhydrous form. However, while cores made from *gassed* silicate/sand mixes exhibit definitely superior disintegration properties to those fabricated from *stoved* silicate/sand mixes, the breakdown obtained is largely inferior to that which may be obtained by conventional oil-sand practice. It is of interest to examine the causative factors contributing to this phenomenon, and, by careful evaluation, to consider possible methods of neutralizing the influence of these conditions.

Extensive observations under controlled conditions leads to the conclusion that the cohesive properties of the silica-gel bond, as it exists in foundry core-sands, is a function of the thermal gradient to which it is exposed. This is well illustrated by the diagrammatic representation of the cohesion curves shown in Fig. 1, the validity of which is well established. In the case of line A, for chill-cast materials, the duration of thermal exposure is short. In the A—B region, which immediately follows casting, virtually no change takes place. Over the B—C region of the curve, the metal is setting in contact with the core, and rapid heat-transfer is taking place. From C—D, the freezing-range is complete, and the casting is removed from the die. From B—D the silica-gel bond is being rapidly deprived of the moisture so essential to its bonding properties, and the disintegration of the core is thus greatly facilitated. This breakdown process is accelerated by the mechanical force created by the contraction of

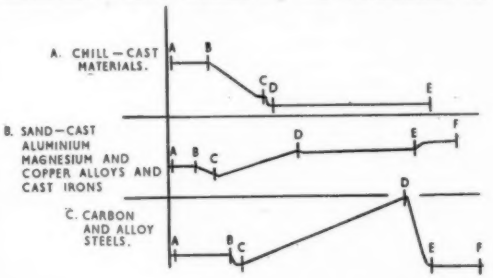

FIG. 1.—*The cohesive properties of silica gels under varying conditions.*

the cooling metal, and it has been said (with considerable justification) that "CO_2-bonded cores run like salt from die-castings." There is a specific advantage in the application of silicate/carbon-dioxide cores to die-casting, in that the amount of gas evolved is negligible in comparison with oil- or resin-bonded cores. It is a function of the short freezing-range of chill-cast materials that such cores show grossly distorted thermal sensitivity.

The picture presented by Fig. 1 curve C (carbon and alloy steels) is very different from the above. The A—B region of relatively small thermal-re-

sponse is common to both curves, but there the similarity ends. From B—C there is, for a short time, a loss of strength due to dehydration of the silica-gel bond. This transition period is quickly passed, however, and strength increases rapidly to a maximum at D. This is followed by a period of decreasing strength from D—E, and over E—F excellent disintegration properties are obtained.

When curve B is examined (aluminium, magnesium, and copper alloys, and cast iron) the trend is indicative of the poor disintegration which is obtained when running these materials over silicate-bonded cores. The A—B region is again common, as is the B—C region. C—D indicates an increasing bond, which does not, however, cease to develop at D, but continues to E. From E—F there is again a slight increase in strength, and the end products show little or no tendency to breakdown. Indeed, many cores which have been used with this range of alloys have properties more to be desired in a building material that one destined for foundry application.

Explanations

So much for the reaction of silicate cores to the various types of thermal gradient. What of causation? The reason for the good breakdown associated with *curve A* has already been touched upon—simple loss of strength resulting from the dehydration of the silica-gel bond.

Curve C presents a rather more complex case; in order to understand this curve it is necessary to examine it in the light of the chemistry of the process. An examination of the formulae given makes it clear that the final product of the gassing process (in a *completely* gassed core) is a mass of sand grains surrounded by a mixture of sodium carbonate and silica-gel. Exposed to the thermal conditions represented by curve C the following reaction occurs over the B—C region:—

$$SiO_2 + Na_2CO_3 + (SiO_2)(H_2O) =$$
$$SiO_2 + Na_2CO_3 + (SiO_2) + H_2O$$

This accounts for the transitional loss of mechanical properties. Over the steep thermal increment of C—D, however, a secondary reaction takes place between the surface of the sand-grain and the residual sodium carbonate.

$$SiO_2 + Na_2CO_3 = Na_2SiO_3 + CO_2$$

The CO_2 escapes from the core-mass at too great a rate for any reactional reversion to occur, and the result is a core bonded with highly viscous sodium silicate—plastic, but exhibiting no tendency to collapse. While this reaction is occurring it is accompanied by an interesting and significant side reaction. By the very nature of their mode of manufacture most silicates contain an indefinite excess of alkali, which is available to add to the magnitude of the reaction exemplified above. The complete silicate/alkali reaction which occurs at the surface of the sand grain produces a neutral silicate bond of such high viscosity as to be virtually solid, even at the high temperature of steel. This bond exhibits a high degree of brittleness, characteristic of such highly viscous liquids as pitch and glass.

Over the descending temperature-range, D—E, the silicate bond increases rapidly in viscosity, and at E the end product is virtually a glass core. Over the E—F portion of the curve, knocking-out of castings moulded in this medium presents no problem.

Curve B represents the unhappy half-way house between the extremes of curves A and C. A—B—C are again common, and trouble does not commence to develop until the C—D range is approached. Over this range, the temperature is sufficiently high to cause the primary silica/sodium carbonate reaction to take place, but not high enough to cause the secondary silica/inherent-alkali reaction to occur. One is, therefore, left with a plastic sand bond sufficiently viscous to be highly tenacious and yet not viscous enough to shatter. As the casting cools, this viscosity increases over the D—E—F range, and the ultimate product is sand bonded with alkaline silicate. In essence, as a function of a specific thermal gradient, one has the very set of conditions which proved an insuperable problem to those early essays in the foundry application of alkaline, silicates have been arrived at, and the crux of the problem remaining is seen to be that which is stated in the title of this article—dissolution of the silicate bond.

Improving Breakdown

Most of the approaches to the problem of improving breakdown with CO_2-bonded cores have been based upon the addition of thermal-sensitive organic materials to the silicate bonding agent, or to the sand mix. This technique, whilst having some effect upon knock-out qualities, is based upon a fundamental misconception. When a silicate/sand mass is compacted, the thin silicate films covering individual grains unite to form liquid agglomerates in the interstices of the mass. The theory behind the use of organic breakdown agents is that their addition introduces reaction centres capable of high thermal response, and a consequent weakening of the silicate bond. The fact of the matter is that such coarse aggregate additions have little influence in the temperature range which produces secondary silicates, for these secondary products unite by mutual capillary attraction to heal the trauma created by the dissolution of the organic addition. A further objection to this type of addition is to be found in the fact that, when added in quantities sufficiently great to exhibit a useful effect, they have a pronounced adverse influence on the hardness and resistance to abrasion of the core.

What is needed is an addition which will have two major effects:—(1) Neutralization of the inherent alkalinity of the silicate, and (2) ability to *dissolve* in the silicate to produce a *molecular* dispersion of material with a high thermal response. One such material, namely cane sugar, used in conjunction with normal silicates, has been found to give breakdown properties equivalent to normal oil-sand mixes, and in many cases superior to them. Continued research will no doubt produce other materials capable of giving equivalent results at a somewhat lower cost.

The Author is indebted to Mr. W. D. Mendham, of Kent Alloys, Limited, for permission to publish this article.

Industrial Injuries Acts

At the request of Mr. John Boyd-Carpenter, Minister of Pensions and National Insurance, the Industrial Injuries Advisory Council is to review the terms of prescription of the diseases included in the Schedule of Prescribed Diseases for the purposes of the National Insurance (Industrial Injuries) Acts. A sub-committee of the Council will consider whether there should be any changes in the terms in which the diseases concerned and the occupations at risk are defined.

The effect of prescribing a disease in relation to an occupation is to enable persons who think they may have contracted that disease from their employment to make an application under the Industrial Injuries scheme and to obtain Industrial Injuries benefit if the disease has been contracted in that way. The benefits provided under that scheme are in general more favourable than those of the main National Insurance scheme.

The sub-committee has decided to direct its attention particularly to certain diseases, which include poisoning by benzene derivatives, skin lesions due to tar, pitch, bitumen, mineral, dermatitis, "beat" hand, "beat" knee, "beat" elbow, and tenosynovitis of the wrist, and tuberculosis. Persons or organizations who consider that changes should be made in the way in which any of these diseases (or others in the schedule) are prescribed are invited to submit written evidence to the secretary, Industrial Injuries Advisory Council, 10, John Adam Street, London, W.C.2, to arrive not later than October 31. An explanatory memorandum can be obtained on request.

The Minister has not asked the Council on this occasion to consider pneumoconiosis or byssinosis or any diseases not already included in the schedule.

Machine-tool Order Books

Machine-tool makers according to the latest returns (for May), have been adding business to their order-books, although the number of orders has fallen off. Inability to expand production has kept deliveries down. New orders fell in May for the third consecutive month, home orders reaching their lowest level of the year at £5,480,000. Export orders remained constant. Deliveries, which rose in the first quarter of the year, declined in April and May, due to some extent to the continued shortage of certain qualities of steel, but in the main to the difficulties makers have been experiencing in recruiting skilled labour.

Deliveries in May, at £6,240,000, were well below the total of home and export orders at £7,140,000, and at the end of the month the total orders in hand was £104,800,000, equivalent to about 15 months' production at the output rate registered in the first five months. Of the £104,800,000 total home orders represented £82,410,000.

The machine-tool makers evidently can be sure of full-time employment for a long time yet and on the short-term basis need not be too greatly concerned at the falling off in orders; the long-term outlook is another matter. Completion dates are as important in selling machine tools as they are in any other business enterprise and an easing of the labour situation in some of the producing areas may assist in bringing deliveries to a higher level.

Mr. A. GILLOTT has been appointed secretary to the Wolverhampton Metal Company, Limited, in succession to Mr. R. M. PARKER who shortly leaves for Adelaide, S. Australia. Mr. R. G. HUGHES becomes deputy secretary.

Jet Inventions for Industry

The establishment of a new technical developments division by the Gloster Aircraft Company, Limited, Hucclecote, Gloucester, is intended to make the company's experience of jet aircraft technology available to industry generally. The company, which is a member of the Hawker Siddeley Group, Limited, believes that many devices originally developed to overcome engineering problems associated with high-speed, high-flying jet aircraft could have a wider application, but previously the company has been too busy on defence and other work to devote its resources to turning them to commercial use. The new division, however, will seek general industrial application for Gloster patents and, in addition, will develop, produce, and market specialized components for use in aircraft systems and guided weapons.

The division will be in the charge of Mr. Eric W. Absolon, who is the company's chief of engineering research. He is 32. Mr. Absolon will be responsible directly to Mr. R. W. Walker, the chief designer, and Mr. R. V. Atkinson, the works director, under the overall direction of Mr. P. G. Crabbe, managing director of the company. Mr. R. F. G. Carse, the sales manager, has been appointed to devote his full time to market research and sales on behalf of the division, which will occupy a 35,000-sq ft. research building now under construction. Modern and comprehensive equipment will be fitted into the new building, while the technical developments division will have full call on the company's facilities for production and development. It is stated that the possible application of electro-hydraulic servo equipment for aircraft controls to mining machinery appears to be extensive, while it is believed that developments in the control of liquids and gases in the pressurized fuel systems of jet aircraft could lead to many industrial applications.

Incorrect Mixture Causes Fatalities

The mixing of ingredients for a special alloy contrary to the standard practice and instructions may have caused the explosion which resulted in the deaths of two brothers, James and Jack Cadman, chargehand, and second chargehand, respectively, of the London and Scandinavian Metallurgical Company, Limited, Rotherham, it was stated at a resumed inquest at Rotherham on August 15. Witnesses said there was a brilliant white flash and the two brothers who were injured died the following day, July 25. Mr. John Hancock, manager of the firm, said that a weighbook had been found after the explosion and figures in this indicated that the mix had been prepared contrary to standard practice and instructions. The book showed that the quantities had been weighed out in total instead of half quantities, and he said that this could have caused the explosion. A verdict of "accidental death" was returned.

Investment Order, 1956

The Treasury have made the Investment Allowances (Fuel Economy Plant) Order, 1956. Section 15(3)(b) Finance Act, 1956, provides that investment allowances are to be continued for expenditure incurred after February 17, 1956, on prescribed fuel-saving plant if it is installed by way of modification or replacement of plant in use in the United Kingdom. This Order, made under Section 15(4), prescribes a list of the fuel-saving plant and the conditions, if any, upon which such plant is prescribed. The Order (SI 1956, No. 1295) came into operation on August 23.

Company News

NORTH BRITISH LOCOMOTIVE COMPANY, LIMITED—Consideration of the dividend of the 5 per cent. cumulative preference shares is deferred until the results for 1956 are available.

GEORGE COHEN SONS & COMPANY, LIMITED—The directors announce that the consent of the Capital Issues Committee to an issue of £1,500,000 unsecured loan stock has been received. The terms on which the stock will be issued will be announced later.

GAS PURIFICATION & CHEMICAL COMPANY, LIMITED—Trading profit of the group rose from £338,044 for 15 months to £516,836 for the year to March 31 last. The company is to declare an interim dividend in March of each year and with it an interim report on group earnings.

TRIANCO, LIMITED, concrete machinery and plant specialists, etc., of East Molesey (Surrey)—At 6 per cent., less tax, for 1955, the ordinary dividend is halved and no participating dividend is being paid on the 6 per cent. preference shares, against 3 per cent. The consolidated net profit, before taxation, is £34,690, against £55,371.

LIGHTALLOYS, LIMITED—The directors announced on August 28 that negotiations were proceeding, but had not yet been concluded, for a cash offer to be made for the purchase of the share capital of the company and its outstanding 6½ per cent. convertible debenture stock. Shareholders and debenture stock holders were recommended to refrain from selling their holdings pending the outcome of the negotiations. On the following day, however, the directors stated that their earlier announcement was made in error as the negotiations which were proceeding were not on a cash basis.

MONSANTO CHEMICALS, LIMITED—Further developments in the manufacture in Britain of new industrial chemicals from petroleum were announced on August 29 by the company, which proposes to spend some £8,500,000 on the first stage of a long-term expansion programme. The company's turnover for the first half of 1956 is the highest recorded for any first six months of a year and is equal to an increase of 6.4 per cent. over the corresponding period of 1955. Export business is up by 5½ per cent. on the same basis. The company states that increased costs and stabilized prices have resulted in reduced profit margins.

Contracts Open

The dates given are the latest on which tenders will be accepted. The addresses are those from which forms of tender may be obtained. Details of tenders with the reference ESB can be obtained from the Board of Trade Export Services Branch, Lacon House, Theobalds Road, London, W.C.1 (telephone: CHAncery 4411, ext. 738 or 771), unless otherwise stated.

BURMA, September 18—Copper and brass piping, for the Union of Burma Purchase Board. (ESB/21339/56.)

BURMA, September 18—Cast-iron drain and soil pipes, for the Director General, Union of Burma Purchase Board. (ESB/21340/56.)

SYRIA, September 10—Iron water piping with accessories, for the Municipality Souedia. (ESB/21474/56.)

AUSTRALIA, October 4—Overhead travelling cranes, for the Queensland Railways. (ESB/21040/56.)

BURMA, September 11—Transformers, generators, and converters for the Director-General, Union of Burma Purchase Board. (ESB/20941/56.)

FORMOSA, September 20—Mining machinery and equipment, for the Central Trust of China, Purchasing Department. (ESB/21295/56/ICA.)

INDIA, September 11—Electrically-driven centrifugal pumping set, for the Director-General of Supplies and Disposals. (ESB/20988/56.)

INDIA, September 13—Machine tools, for the Government of India, Indian Supply Mission. (ESB/21421/56.)

New Patents

(Copies of complete specifications are obtainable from the Patent Office Sales Branch, 25, Southampton Buildings, Chancery Lane, London, W.C.2, price 2s.)

752,406. General Electric Company, Schenectady, 5, N.Y., USA.

Improved methods and apparatus for making cast-iron windings in dynamo electric-machine rotors. In combination with a metallic-mould structure is a moulding jacket of heat-resistant readily deformable material. Means are provided for compressing the jacket within the mould structure so as to cause the material to partially enter the slots. Metal is introduced into the slots to form the cast winding. After removal of the core and cast winding from the jacket the core periphery may be reduced to a diameter greater than the overall diameter of the cast winding within the slots.

752,441. Atomic Energy of Canada, Limited, No. 7, Temporary Building, Sussex Street, Ottawa, Ontario, Canada.

One or more reactive metals from the group consisting of neptunium, cerium, and americium are alloyed with one of a group of reducing metals consisting of aluminium and beryllium. A halide of the reactive metal is mixed with the reducing metal at 700—1,200 deg. C. in vacuum, being thus heated to reduce the halide and form the alloy. The halide of the reducing metal is distilled off during the reaction.

752,474. Philips Electrical Industries, Limited, Spencer House, South Place, Finsbury, London, E.C.2.

Methods of manufacturing anistropic permanent magnets having preponderant crystal orientations in the [100] directions, in which the magnet bodies are subjected to a cooling operation in which heat is withdrawn in the desired direction.

752,555. Kuro Kanamori, 36 5-chome, Asagaya, Suginiami-ku, Tokyo-to, Japan, and Yawata Seitetu Kabushiki Kaisha, 1 1-chome, Marunouchi, Chiyoda-kue, Tokyo-to, Japan.

A method for controlling the temperature in a blast furnace which comprises forcing water under pressure and in the liquid phase directly into the molten pig-iron. A change in the temperature of the hearth is thus achieved incidental to the heating of the water, and the change thereof from the liquid into the gaseous phase *in situ* in the molten pig-iron.

752,563. Gebr. Bohler & Company, A.G., 12, Elisabethstrasse, Vienna, 1, Austria.

In the process of continuously casting, more particularly as applied to metals having a high-melting point, use is made of the known type of pipe ladle the pipe of which is preheated by means additional to that for heating the body of the ladle. The pipe is also claimed to have a metal coating (preferably of sheet iron on metal gauze) at the end where the metal is to be poured out.

752,603. General Motors Corporation, Grand Boulevard, Detroit, Michigan, USA.

Apparatus for uniting by adhesive the sections of a shell mould. It consists of a reciprocable mould support, a counter pressure member adapted to co-operation with the support to apply a squeezing pressure to the assembled mould sections. There is also an adhesive applicator head which is swingable so that it may be registered with the mould support in succession to the counterpressure member which is also swingable.

News in Brief

MORFAX, LIMITED, Willow Lane, Mitcham, Surrey, by the completion of extensions have increased their floor area from 20,000 to 33,500 sq. ft.

THE Canadian Car & Foundry Company, Montreal, has formed a new company, Canadian Steel Foundries (1956), to take over its steelfoundry division.

THE COMPLIMENTARY LUNCHEON offered to Sir Alfred Herbert to celebrate his 90th birthday has been cancelled on the advice of Sir Alfred's medical advisers.

SITE WORKS have commenced at Blaydon (Co. Durham) for a new works for Churchill-Redman, Limited, machine-tool manufacturers, of Newcastle-upon-Tyne.

A MINISTRY OF SUPPLY CONTRACT for pressure transducers to the value of £25,005 has been secured by J. Langham Thompson, Limited, electronic development engineers, of Bushey, Herts.

THE Globe Pneumatic Engineering Company, Limited, London, S.W.1, has received a contract from Russia, worth £75,000, for over 200 pneumatic hoists, ranging from ½-ton to 5-ton capacity.

BORAX & CHEMICALS, LIMITED, London, W.C.1, announces that prices of all grades and qualities of "Three Elephant" brand borax and boric acid will be advanced by £1 per ton on October 1.

THE Mayor of the City of New York (Mr, Robert Wagner) has issued a proclamation making the week November 26 to 30, when an exhibition and convention is being held, "Automation Week."

THERE was a total of 524 accidents causing lost time among the personnel of companies in the United Steel Companies, Limited, group in the first half of this year, compared with 531 in the first half of 1955.

THE NATIONAL SOCIETY OF MASTER PATTERNMAKERS are holding a meeting on September 12 at the Charing Cross Hotel, London, W.C.2, at 2.30 p.m., when the subject of a talk by Mr. Taylor will be "Cast Resin Patterns."

BRITAIN'S REPRESENTATIVE at the first industry-sponsored international conference on nuclear reactors, which opened on August 27 at the atomic division of General Dynamics, San Diego (California), is Dr. Peter Fortescue, a deputy chief scientist at the Atomic Energy Research Establishment at Harwell.

A COURSE for foremen and supervisors is to be held at the Birmingham and District Industrial Safety Training Centre, Summer Road, Acocks Green, Birmingham, 27, from September 14 to 15. Those wishing to attend should apply for details to Mr. W. G. Appleyard, 21, Steelhouse Lane, Birmingham, 4.

METROPOLITAN-VICKERS ELECTRICAL COMPAMY, LIMITED, are to erect a new apprentice-training school as part of their £2,250,000 extensions on the 21-acre site leased from Sheffield Corporation in Greenland Road. The new works will be in production in 1958 and an additional labour force of 500 will be required.

DAIMLER DIESEL ENGINES have hitherto been produced only to the extent of the company's own requirements. Manufacturing capacity has now been increased and horizontal and vertical versions of the "650" type 10.6-litre engine, suitable for a wide variety of applications, are now being produced for general sale at home and abroad.

CONTRACTS have been placed for a new factory at Honley, near Huddersfield, for Brook Motors, Limited. The site covers 28½ acres and the total floor area will be 75,000 sq. ft. The works area will be 570 ft. long and 105 ft. wide. The present fractional horsepower motor department at the Empress Works, Huddersfield, will be transferred there.

THE TREASURY have made an Order which exempts blast-furnace ferro-manganese from import duty for a period ending on March 18, 1957. The new Order, the Import Duties (Exemptions) (No. 9) Order, 1956 (S.I. No. 1339), which came into operation on August 31, may be obtained from HM Stationery Office, or from any bookseller (price 3d.; by post, 5d.).

EXAMPLES of British instrumentation in the fields of optics, laboratory apparatus, electrical, electronic, and nucleonic equipment, and measuring instruments are being shown at the St. Eriks Fair, Stockholm, in the first two weeks of September. Thirty-four member firms of the Scientific Instrument Manufacturers' Association, acting in collaboration with the Board of Trade, will stage the display.

THE Gray Iron Founders' Society, the American counterpart of the Council of Iron Foundry Associations, after years of intensive work on the need for the intelligent use of a costing system by foundries is now turning its attention to marketing. It has already appointed to its staff a marketing director—Mr. Richard C. Mclay, and has formed a strong committee, headed by Mr. William S. Thomas, to support his activities.

THE TREASURY has made the Import Duties (Drawback) (No. 11) Order, 1956, which continues the allowance of drawback (previously allowed by the Import Duties (Drawback) (No. 1) Order, 1956) of Customs duty on imported coated aluminium foil (of the kind specified in the Schedule to the Order) used in the manufacture of certain metallic yarn which is exported or shipped as stores.

FOR the fourth time since 1952, the United Steel Companies, Limited, have invited parties of public schoolboys and undergraduates to attend short one-week courses in Sheffield on iron and steel production, research and management. The 27 senior boys invited from public schools will be in residence at Whirlow Grange, Sheffield, from September 10 to 15, and the 39 undergraduates will be accommodated at the University Hall, Sheffield, from September 17 to 22.

FOR THE PRODUCTION of steel castings, the Indian Iron and Steel Company, Limited, of Burdwan, India, are to instal a second 2,000 kva Birlec Lectromelt arc melting furnace. Giving an output of approximately 2 tons per hour, the furnace has a shell diameter of 8 ft. and a capacity of 4 tons. Since 1946 Birlec Limited, Tyburn Road, Erdington, Birmingham, 24, have been commissioned by various Indian companies to build a total of 22 arc melting furnaces in a wide range of capacities.

MORE THAN 100 DELEGATES are expected at the Yorkshire Regional Conference of the Institute of Industrial Supervisors to be held at the factory of W. & T. Avery, Limited, at Sherburn-in-Elmet on September 22. Sir Anthony H. M. Bowlby, vice-president of the Institute and a director of Guest, Keen and Nettlefolds, Limited, will speak on "The Foreman's Future," and Mr. D. H. Turnbull, a member of the Institute of Production Engineers and works director of T. S. Harrison and Sons, Limited, Heckmondwike, on "Automation—a Challenge to the Supervisor."

IMPORTANT DEVELOPMENTS in the manufacture in Great Britain of new industrial chemicals from petroleum are announced by Monsanto Chemicals, Limited, Victoria Street, London, W.1. The company plans to spend some £8,500,000 on the first stage of a long term

News in Brief

expansion programme, and a new factory will be constructed on a 100-acre site alongside the Fawley, Hampshire, refinery of the Esso Petroleum Company, Limited. This factory will provide Monsanto with feedstock for conversion into a wide variety of raw materials for use in the plastics, textile, rubber, paint, paper and other manufacturing industries.

AT the Society of British Aircraft Constructors exhibition at Farnborough this week, the foundries division of David Brown Industries, Limited, on stand No. 202, are showing a selection of high-tensile steel components including centrifugally spun castings in austenitic heat-resisting steel and nickel/chrome alloys, nimonic 75 and nimonic 90, for gas-turbine use. Examples are also shown of castings produced by the investment process, and other exhibits include gears and gear units of the type used in aircraft and engine manufacture, testing and maintenance and a selection of precision gear-cutting tools and measuring equipment.

THE POSSIBILITIES of shipbreaking as an alternative employment in Scapa Flow, whose naval establishments are to close down, are put forward by Mr. Wingfield Digby, the Civil Lord of the Admiralty, in a letter to Mr. J. Grimond, MP for Orkney and Shetland. The letter says that representatives of the Admiralty and the Board of Trade recently inspected the available buildings at Lyness, in Scapa Flow, many of which "would be suitable for adaptation for industrial purposes. It is, however, doubtful whether a manufacturing industry requiring skilled labour could be established satisfactorily at Lyness because of the lack of local skilled labour . . . Shipbreaking might be established at Lyness using local labour, if given some training."

THE STEEL COMPANY OF WALES has announced that in order to improve sales service to sheet customers throughout the country a scheme has been initiated under which four firms have accepted appointments as "Accredited Sheet Stockholding Merchants" to the company. The main purpose of the scheme is to offer broad distribution of excess and defective sheet products throughout England and Wales and to assist the buyer of smaller tonnages in obtaining supplies of prime material which might otherwise be difficult to obtain directly from works. The appointed merchants are:—John Cashmore, Limited, Newport, Mon; Ductile Steel, Limited, Jubilee Works, Willenhall, Staffs; John Lysaght (Bristol Works), Limited, 66, Cannon Street, London, E.C.4, and Roberts, Sparrow & Company, Limited, St. Mark's Street, Wolverhampton, Staffs.

BRITISH LABORATORY WARE ASSOCIATION announces that as a contribution to the price stabilization policy of the Government, the laboratory furnishers who are members of the Association have decided to stabilize the prices of the laboratory equipment and apparatus, other than chemicals, they manufacture and distribute, for a period of six months from September 1, 1956. This decision applies to the prices, for the home and export markets, fixed by each laboratory furnisher individually for its own proprietary goods and for non-proprietary goods and is subject to the costs of materials and wage rates remaining stable. In order to make this policy as effective as possible the Association approached the principal manufacturers of proprietary goods, for whom the laboratory furnishers act as stockists and distributors, and has obtained an encouraging measure of collaboration in this policy of price stabilization. The laboratory furnishers will, however, have to charge for proprietary goods at the prices fixed by individual manufacturers.

Beilby Memorial Awards

From the interest derived from the invested capital of the Sir George Beilby Memorial Fund, at intervals to be determined by the Administrators representing the Royal Institute of Chemistry, the Society of Chemical Industry and the Institute of Metals, awards are made to British investigators in science to mark appreciation of records of distinguished work. Preference is given to investigations relating to the special interests of Sir George Beilby, including problems connected with fuel economy, chemical engineering and metallurgy. The awards are made, not on the result of any competition, but in recognition of continuous work of exceptional merit bearing evidence of distinct advancement in science and practice.

In general, awards are not applicable to workers of established repute but are granted as an encouragement to younger men who have done original independent work of exceptional merit over a period of years. The administrators are empowered to make more than one award in a given year if work of sufficient merit by several candidates is brought to their notice. For 1956 two awards were made, each of 150 guineas, to Dr. F. D. Richardson and Dr. F. Wormwell. Consideration will be given to the making of an award or awards from the fund early in 1957. Outstanding work of the nature indicated may be brought to the notice of the administrators, either by persons who desire to recommend the candidate or by the candidate himself, not later than December 31, 1956, by letter addressed to the Convenor of the Administrators, Sir George Beilby Memorial Fund, The Royal Institute of Chemistry, 30, Russell Square, London, W.C.1.

The letter should be accompanied by nine copies of a short statement on the candidate's career (date of birth, education and experience, degrees and other qualifications, special awards, etc., with dates) and of a list of titles, with references, of papers or other works published by the candidate, independently or jointly. Candidates are also advised to forward one reprint of each published paper of which copies are available.

Public Works Exhibition

With the Queen as Patron, the Public Works and Municipal Services Congress and Exhibition opens at Olympia on Monday, November 12. More than 360 exhibitors, of which about 10 per cent. operate foundries, will provide a display embracing every class of machinery, plant, material and appliance essential to public and local authorities anywhere in the world. Concurrently, the congress will provide in its nine sessions an opportunity for the exchange of ideas and information on an international scale (in 1954, delegates from 83 countries attended). It will be opened by the Minister of Housing and Local Government.

Recent Wills

WADDINGTON, EDWIN, retired ironfounder, of Southport £11,103

FIELD, CLAUDE, a director of G. Clancey, Limited, ironfounders, etc., of Halesowen (Worcs) £11,371

DIXON, A. S., a director of S. Dixon & Son, Limited, non-ferrous metal founders, etc., of Leeds ... £11,860

SHAW, JOSEPH, formerly a representative of William Barraclough, Limited, range manufacturers and general ironfounders, of Stanningley, Leeds ... £6,158

ELLIS, SIR ROBERT GEOFFREY, BT., late president and former chairman of the Monotype Corporation, Limited, who also had interests in coal, engineering, etc. £258,515

HARPER, LEONARD, a former London manager and a director of Horseley Bridge & Thomas Piggott, Limited, engineers and ironfounders, etc., of Tipton (Staffs) £4,099

WHO USES FULBOND?

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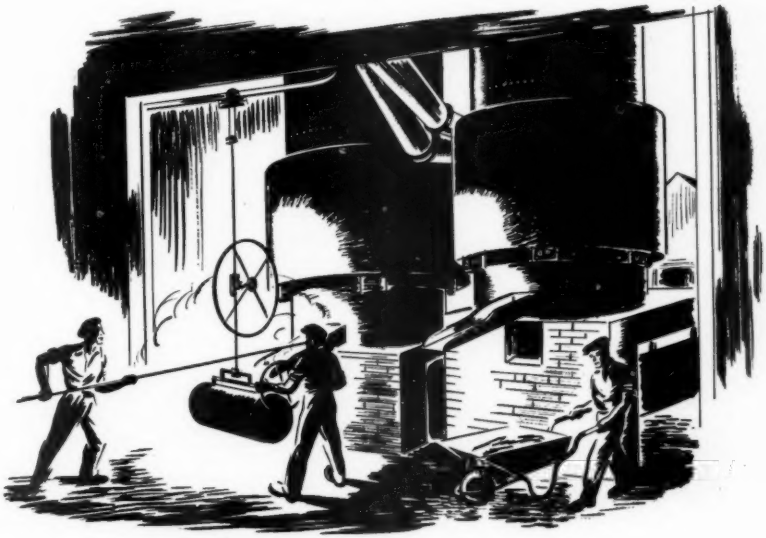

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Telephone: REDHILL 3521

CMF11

Personal

Mr. G. S. HELME, who has been actively associated with the Lancashire Dynamo group for over 50 years, was the guest of honour at a cocktail party given on Wednesday at the Central Hotel, Glasgow, to mark his retirement from the company.

Mr. G. C. ORAM, manager of the central engineering workshops at Appleby-Frodingham Steel Company, Scunthorpe, has been additionally appointed technical consultant, engineering works, to the United Steel Companies, Limited. He remains responsible for the central engineering workshops.

Mr. J. G. SHAW, who founded the Willesden works of Lancashire Dynamo & Crypto, Limited, 60 years ago, celebrated his 80th birthday on August 26; this year is also his 50th wedding anniversary, and to mark these occasions Mr. Shaw was presented recently with a portrait of himself in oils.

Mr. J. E. DOBSON, tool specialist and demonstrator with Edgar Allen & Company, Limited, Sheffield, retired recently. He had been with the company since January, 1930. Mr. Dobson's duties have taken him into machine shops throughout this country and also in Norway, Holland, Belgium, Switzerland, and Italy.

The mission which is going to India in October " to advise on the further expansion of heavy machinery manufacturing capacity during the period of the second five-year plan " will be under the chairmanship of Sir ERIC COATES, chairman of the Overseas Food Corporation, who led the successful steel mission to India last year.

At the Park Works, Lockwood, Huddersfield, recently, Mr. A. AVISON, deputy managing director of the David Brown Organization, presented gold wrist watches to Mr. FRANK CRAWSHAW, a foreman patternmaker, aged 65, and Mr. GEORGE WILLIAM BROOK, a tool grinder, aged 71, who had both completed 50 years' service with the concern.

Mr. J. C. BOVILL, managing director of Newton Chambers & Company, Limited, Chapeltown, Sheffield, presented the awards at the 20th annual show of the Thorncliffe Horticultural Society held in the works canteen last month. The Sir Samuel Roberts cup for the highest number of points was won by Mr. H. CROWTHER.

After 20 years as head of the repairs and despatch department of Wm. Doxford & Sons, Limited, engineers and shipbuilders, of Sunderland, Mr. ROBERT O. CUNNINGHAM has retired at the age of 73. Mr. Cunningham was formerly secretary of George T. Gray & Company, Limited, marine engine builders, of South Shields, which closed down many years ago.

The Maudslay Society and the Junior Institution of Engineers announce the Maudslay scholarship awards for 1956. Mr. COLIN R. EVANS and Mr. M. J. C. SWAINSTON, both of whom are apprentices in their final year with the Ministry of Supply at the Royal Ordnance Factories, Woolwich, each receive scholarships of £100 value. Special prizes of £50 each have been awarded to Mr. M. COXHILL, Mr. B. A. GRAHAM, Mr. N. E. RUNDLE, and Mr. R. G. WILLSON. The scholarships, established to perpetuate the name of Henry Maudslay and directed to the encouragement and assistance of young engineers under training, are awarded annually, by selection. The funds are provided from the Maudslay Scholarship Foundation, endowed from the covenanted donations of the members of the Maudslay Society, and the Junior Institution of Engineers joins in the administration of the scholarships and the selection of candidates.

Obituary

Mr. T. F. BAILEY, registrar of the Sheepbridge Coal & Iron Comany, Limited, for 37 years, died at his Chesterfield home on August 17.

Mr. EUGENE R. FEATONBY, erection superintendent of the Tees Side Bridge & Engineering Works, Limited, Middlesbrough, has died at the age of 67. He joined the firm more than 50 years ago.

Mr. PERCY EDMUNDS, whose death is reported at the age of 80, was managing director of Walter P. Edmunds, Limited, malleable and grey iron and brass founders, of Wednesbury (Staffs), until his retirement two years ago.

Mr. GEORGE MAURICE WRIGHT, who became engineer-in-chief of Marconi's Wireless Telegraph Company, Limited, in 1946, died on August 26 at the age of 65. In 1948 Mr. Wright was appointed a member of the Radio Research Board of the Department of Scientific and Industrial Research. He was appointed C.B.E. in 1950 and some four years later relinquished his position as engineer-in-chief to become a full-time technical consultant to the company.

Increases in Capital

MANOR ENGINEERING COMPANY, LIMITED, Fenton, Stoke-on-Trent, increased by £30,000, in £1 ordinary shares, beyond the registered capital of £10,000.

WILLIAM HALL (STEEL STOCKHOLDERS), LIMITED, Blackheath (Staffs), increased by £15,000, in £1 ordinary shares, beyond the registered capital of £10,000.

BRAYHEAD INDUSTRIES, LIMITED, engineers, founders, etc., of Ascot (Berks), increased by £199,900, in 5s. ordinary shares, beyond the registered capital of £100.

HOWARD PNEUMATIC ENGINEERING COMPANY, LIMITED, Eastbourne (Sussex), increased by £10,000, in £1 ordinary shares, beyond the registered capital of £13,000.

CHARLES CLIFFORD, LIMITED, non-ferrous metal manufacturers, of Birmingham, increased by £165,000, in £1 ordinary shares, beyond the registered capital of £435,000.

WARD & DAVIDSON, LIMITED, coppersmiths, brassfounders, etc., of Sunderland, increased by £20,000, in £1 ordinary shares, beyond the registered capital of £20,000.

HILGER & WATTS, LIMITED, scientific instrument makers, etc., of London, S.E.5, increased by £185,500, in 5s. ordinary shares, beyond the registered capital of £412,500.

HUNT & MOSCROP (MIDDLETON), LIMITED, bleachers' engineers, etc., of Middleton (Lancs), increased by £50,000, in 1s. ordinary shares, beyond the registered capital of £170,000.

HICK, HARGREAVES & COMPANY, LIMITED, engineers, ironfounders, etc., of Bolton (Lancs), increased by £450,000, in £1 shares, beyond the registered capital of £800,000.

CHUBB & SON'S LOCK & SAFE COMPANY, LIMITED, increased by £50,000, in 50,000 ordinary shares and 200,000 " A " ordinary shares of 4s., beyond the registered capital of £600,000.

MCINTYRE & SONS, LIMITED, structural engineers and steelwork contractors, of Liverpool, increased by £30,000, in 1s. ordinary shares, beyond the registered capital of £60,000.

HUDSON & WRIGHT, LIMITED, makers of seamless brass and copper tubes, of Birmingham, increased by £200,000, in 2s. ordinary shares, beyond the registered capital of £200,000.

DEWHURST & PARTNER, LIMITED, makers of electric starters and magnetic brakes, of Hounslow (Middx), increased by £180,000, in 2s. shares, beyond the registered capital of £180,000.

Board Changes

BENNIS COMBUSTION, LIMITED—Mr. G. M. Mellor has been appointed chairman and joint managing director with Mr. Fred Howarth.

FIRTH-VICKERS STAINLESS STEELS, LIMITED—Mr. J. T. W. Dewar, deputy managing director, has been appointed joint managing director.

SWAN, HUNTER, & WIGHAM RICHARDSON, LIMITED—Mr. G. B. Halley, managing director of the Wallsend Slipway & Engineering Company, Limited, has been appointed a director of the company. He joined Wallsend Slipway & Engineering seven years ago and was appointed managing director last May.

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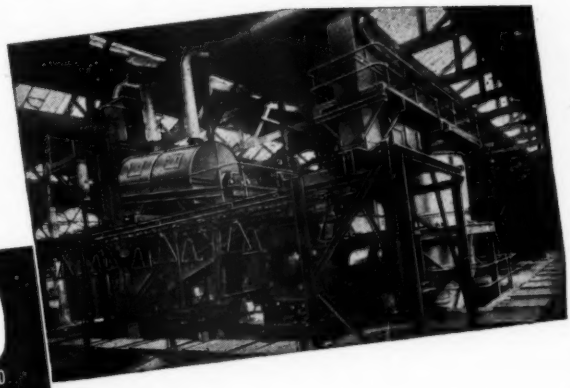

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Raw Material Markets

Iron and Steel

The output of basic iron for the steelworks continues at a high level. Some of the furnaces in Derbyshire and Northamptonshire which normally produce high-phosphorus foundry pig-iron are still producing basic iron. Supplies of high-phosphorus iron are, nevertheless, adequate for current requirements, although stocks generally are not high either at the furnaces or at consuming points. The light foundries are urgently in need of more work and it is hoped that trade will show its usual seasonal expansion within the next few weeks.

Although the call for both hematite and low-phosphorus iron from the motor and allied trades remains restricted, demand is maintained by the general engineering, machine-tool, and other users of these grades. Refined pig-iron is rather quiet, due to the reduced requirements of the motor trade.

Foundry coke is forthcoming as required, while supplies of scrap have improved during the past month or two. No difficulty is experienced by the foundries in covering their needs in ganister, limestone, and firebricks.

There has been an increase in the last week or two in the tonnage of imported billets coming through for the re-rollers. This, coupled with the holiday period, during which stocks of billets accumulated, has given the re-rollers a more satisfactory stock position. Some, in fact, are suspending deliveries for a week or so to enable them to work off accumulated supplies. The re-rollers are busy in the production of light sections, small bars, and strip, with plenty of business offering from home sources and also from abroad, although little enough of the overseas trade can be accepted. Most of the re-rollers have covered their potential outputs up to the end of the year.

Non-ferrous Metals

The Cairo discussions overshadow the metal markets and, accordingly, activity is at a low ebb, and until the final communiqué is issued rumour will be the arbiter of prices. This comment requires some qualification in relation to copper, as this market is also deeply concerned with the outcome of the discussions currently underway between the Steel Workers' Union and the Kennecott Copper Company, whose copper output, amounting to about 21,000 tons a month, is refined at the Garfield refinery owned by the American Smelting & Refining Company. Latest advices are that the two sides are still very far apart. The combined uncertainty of these two events has hardened the copper price in London and has resulted in a firmer undertone in New York, with scrap copper up ¼ cent to 32¼ cents a pound.

In Rhodesia, the threat of the African Mineworkers' Union to prevent Africans working overtime on the Copperbelt mines has not as yet been tested. So far there are no reports from any source indicating that the natives are refusing to work overtime in any way that would suggest that the threat was in operation. Attention has, however, been drawn to the point that this type of labour disturbance could be serious if the union decided to classify Sunday working as overtime. At Roan Antelope a strike was called on Sunday as a protest against the mine management's refusal to meet a deputation from the union while the overtime ban was still in operation. And on Tuesday something more in the nature of a general strike was called by the union over the question of the necessity of Africans to wear protective leg guards underground. The union instructed its members to refuse to wear the leg guards, and although not all of the members of the union obeyed the instructions, thousands of daily-paid Africans came out on strike, affecting production at all the mines throughout the Copperbelt.

Tin is quiet both here and in New York. The undertone is firm, a fact reflecting the metal's sound statistical position. Indeed, with little, if any, surplus metal available for the rest of the year, there is not much likelihood of the International Tin Pool operating in the market before 1957.

Lead is firm, but quiet on both sides of the Atlantic. Zinc continues its revival; in the United States both "Prime Western" and special high-grade metal is wanted by the galvanizing trade and diecasters respectively. The growing improvement is largely attributed to the return of the steel industry to slightly over 96 per cent. of rated capacity.

Official metal prices were as follow:—

COPPER, Standard—*Cash:* August 30, £301 to £301 10s.; August 31, £305 10s. to £306; September 3, £304 10s. to £305 10s.; September 4, £304 to £304 10s.; September 5, £309 to £309 10s.

Three Months: August 30, £300 10s. to £301; August 31, £305 to £305 10s.; September 3, £304 to £304 10s.; September 4, £304 to £304 10s.; September 5, £308 to £309.

TIN, Standard—*Cash:* August 30, £768 to £769; August 31, £772 to £773; September 3, £766 to £767; September 4, £771 to £772; September 5, £771 to £772.

Three Months: August 30, £765 to £766; August 31, £769 to £770; September 3, £764 to £765; September 4, £767 to £768; September 5, £767 10s. to £768.

LEAD—*Second half August:* August 30, £115 5s. to £115 15s.; August 31, £115 15s. to £116. *First half September:* September 3, £116 to £116 5s.; September 4, £116 10s. to £117; September 5, £116 15s. to £117.

Second half November: August 30, £114 5s. to £114 10s.; August 31, £114 10s. to £114 15s. *First half December:* September 3, £114 5s. to £114 10s.; September 4, £114 15s. to £115; September 5, £114 15s. to £115.

ZINC—*Second half August:* August 30, £94 15s. to £95 5s.; August 31, £95 10s. to £95 15s. *First half September:* September 3, £95 5s. to £95 15s.; September 4, £95 15s. to £96 5s.; September 5, £96 5s. to £96 10s.

Second half November: August 30, £93 15s. to £94; August 31, £94 5s. to £94 10s. *First half December:* September 3, £93 10s. to £93 15s.; September 4, £93 15s. to £94; September 5, £94 5s. to £94 10s.

German Steel Plant for India

According to messages from Bonn, the Krupp company has secured orders worth £10,000,000 in connection with the Rourkela steelworks project in India. They include four open-hearth furnaces and three converters working on the Linz-Donawitz principle.

Estimated cost of the Rourkela project, which is expected to be operating by 1959, is £75,000,000. Placing of the contract is now being completed. Orders for the rolling-mill plant are expected to be placed shortly, and to go to a consortium made up of Krupp, Demag, Schloemann, and other manufacturers. It is thought that a 60-in. strip mill by Demag will be included. Orders already placed include three blast furnaces by Gutehoffnungshütte.

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Engineers
WESTWOOD WORKS - PETERBOROUGH

Current Prices of Iron, Steel, and Non-ferrous Metals

(Delivered unless otherwise stated)

September 5, 1956

PIG-IRON

Foundry Iron.—No. 3 IRON, CLASS 2:—Middlesbrough, £17 11s. 0d.; Birmingham, £17 3s. 3d.

Low-phosphorus Iron.—Over 0.10 to 0.75 per cent. P, £20 8s. 0d., delivered Birmingham. Staffordshire blast-furnace low-phosphorus foundry iron (0.10 to 0.50 per cent. P, up to 3 per cent. Si), d/d within 60 miles of Stafford, £20 12s. 3d.

Scotch Iron.—No. 3 foundry, £21 14s. 6d., d/d Grangemouth.

Cylinder and Refined Irons.—North Zone, £23 16s. 6d.; South Zone, £23 19s. 0d.

Refined Malleable.—P, 0.10 per cent. MAX.—North Zone, £25 4s. 0d.; South Zone, £25 6s. 6d.

Hematite.—Si up to 2 per cent., S. & P. over 0.03 to 0.05 per cent. :—N.-E. of England (local iron), £21 7s. 6d.; Scotland (Scotch iron), Zone S. 1, £21 14s. 0d.; Sheffield, £22 14s. 6d.; Birmingham, £23 2s. 0d.; Wales (Welsh iron), £21 7s. 6d.

Basic Pig-iron.—£18 3s. 0d. all districts.

FERRO-ALLOYS

(Per ton unless otherwise stated, delivered)

Ferro-silicon (6-ton lots and over).—45 per cent. Si, £48 0s. 0d. to £50 5s. 0d., scale 16s. 0d. to 17s. 6d. per unit; 75 per cent. Si, £70 0s. 0d. to £73 2s. 6d., scale 16s. 0d. to 17s. 6d. per unit.

Ferro-vanadium.—50/60 per cent., 27s. 6d. per lb. of V.

Ferro-molybdenum.—65/75 per cent., carbon-free, 11s. 6d. per lb. of Mo.

Ferro-titanium.—20/25 per cent., carbon-free, £250 0s. 0d.; 38/40 per cent., £299 0s. 0d.

Ferro-tungsten.—80/85 per cent., 17s. 0d. per lb. of W.

Tungsten Metal Powder.—98/99 per cent., 20s. 0d. per lb. of W.

Ferro-chrome (6-10 ton lots).—4/6 per cent.C, £93 10s.0d. to £95 0s. 0d., basis 60 per cent. Cr, scale 29s. 9d. to 32s. 0d. per unit; over 6 per cent. C, £92 10s. 0d. to £93 0s. 0d., basis 60 per cent. Cr, scale 29s. 9d. to 32s. 0d. per unit; 2 per cent. C,* 2s. 1d. per lb. Cr; 1 per cent. C,* 2s. 1½d. per lb. Cr; 0.15 per cent. C,* 2s. 2½d. per lb. Cr; 0.10 per cent. C,* 2s. 2¾d. per lb. Cr; 0.06 per cent. C,* 2s. 3d. per lb. Cr.

Metallic Chromium.—98/99 per cent., 7s. 0d. to 7s. 6d. per lb.

Metallic Manganese.—93/95 per cent., carbon-free, £249 0s. 0d.; 96/98 per cent., £259 0s. 0d. to £265 0s. 0d.

Ferro-columbium.—65/75 per cent., Nb + Ta, 22s. 6d. to 23s. 6d. per lb., Nb + Ta.

Ferro-manganese (home).—78 per cent., £66 0s. 0d.

SEMI-FINISHED STEEL

Re-rolling Billets, Blooms, and Slabs.—BASIC: Soft, u.t., £28 19s. 0d.; tested, 0.08 to 0.25 per cent. C, £29 19s. 0d.; hard (0.41 to 0.60 per cent. C), £31 0s. 6d.; silico-manganese, £39 10s. 0d.; free-cutting, £33 3s. 0d. SIEMENS MARTIN ACID: Up to 0.25 per cent. C, £36 14s. 6d., silico-manganese, £39 17s. 6d.

Billets, Blooms, and Slabs for Forging and Stamping.—Basic, soft, up to 0.25 per cent. C, £34 13s. 6d.; basic, hard, over 0.41 up to 0.60 per cent., C, £35 16s. 0d.; acid, up to 0.25 per cent. C, £38 17s. 6d.

FINISHED STEEL

Heavy Plates and Sections.—Ship plates (N.-E. Coast), £35 7s. 0d.; boiler plates (N.-E. Coast), £37 17s. 0d.; floor plates (N.-E. Coast), £36 16s. 0d.; sectional material, N.-E. Coast, £33 16s. 6d.

Small Bars, Sheets, etc.—Rounds and squares, under 3 in., untested (4-ton lots), £36 3s. 0d.; flats, 5 in. wide and under (4-ton lots), £36 3s. 0d.; hoop and strip, £36 12s. 6d.; uncoated strip mill coils, hot rolled, under 3mm. to 12g., £38 16s. 0d.; black sheets (hand mill), 17/20 g., £50 4s. 6d.; galvanized corrugated sheets, 24 g., £62 7s. 0d.

Alloy Steel Bars.—1 in. dia. and up: Nickel, £61 13s. 9d.; nickel-chrome, £85 10s. 6d.; nickel-chrome-molybdenum, £96 16s. 6d.

NON-FERROUS METALS

Copper.—Cash, £309 0s. 0d. to £309 10s. 0d.; three months, £308 0s. 0d. to £309 0s. 0d.; settlement, £309 10s. 0d.

Copper Tubes, etc.—Solid-drawn tubes, 2s. 11¾d. per lb.; rods, 342s. 6d. per cwt. basis: 20 s.w.g., 375s. 9d. per cwt.

Tin.—Cash, £771 0s. 0d. to £772 0s. 0d.; three months, £767 10s. 0d. to £768 0s. 0d.; settlement, £772 0s. 0d.

Lead (Refined Pig).—First half September, £116 15s. 0d. to £117 0s. 0d.; first half December, £114 15s. 0d. to £115 0s. 0d.

Zinc.—First half September, £96 5s. 0d. to £96 10s. 0d.; first half December, £94 5s. 0d. to £94 10s. 0d.

Zinc Sheets, etc.—Sheets, 15 g. and thicker, all English destinations, £127 0s. 0d.; rolled zinc (boiler plates), all English destinations, £124 15s. 0d.; zinc oxide (Red Seal), d/d buyers' premises, £110.

Brass Tubes, etc.—Solid-drawn tubes, 2s. 5½d. per lb.; rods, drawn, 3s. 3d.; sheets to 10 w.g., 320s. 3d. per cwt.; wire, 3s. 0½d.; rolled metal, 305s. 3d. per cwt.

Brass (Brazing).—BS1400, B3 (65/35), £196; B6 (85/15), — ; BS249, —.

Brass (High Tensile).—BS1400, HTB1 (30 tons), £249; HTB2 (38 tons), — ; HTB3 (48 tons), — .

Gunmetal.—BS1400, LG2 (85/5/5/5), £269; LG3 (86/7/5/2), £278; G1 (88/10/2/½), £330 ; (88/10/2/1), £320.

Phosphor Bronze.—BS1400, PB1 (AID released), £340 per ton.

Phosphor Bronze Strip, etc.—Strip, 441s. 0d. per cwt.; sheets to 10 w.g., 465s. 6d. per cwt.; wire, 4s. 6¾d. per lb.; rods, 3s. 10¾d.; tubes, 3s. 9d.; chill cast bars: solids 3s. 10½d., cored 3s. 11½d. (CHARLES CLIFFORD, LIMITED).

Nickel Silver, etc.—Rolled metal, 3 in. to 9 in. wide × 0.056, 4s. 1¾d. per lb.; round wire, 10g. in coils (10 per cent.), 4s. 6d.; special quality turning rod, 10 per cent., ½ in. dia., in straight lengths, 4s. 5d. All prices are net.

Other Metals.—Magnesium, ingots, 2s. 4d. per lb. Antimony, English, 99 per cent., £210 0s. 0d. Quicksilver, ex-warehouse, £83 10s. 0d. Nickel, £519 0s. 0d. Aluminium ingots, £198 10s. 0d.; aluminium bronze (BS1400), AB1, £310; AB2, . £318 Solder, brazing, BS1945, type 8 (50/50), 3s. 1d. per lb., type 9 (54/46), 3s. 4½d. per lb.

* Average 68–70 per cent.

Publications Received

Training for a Career. Issued by the English Steel Corporation, Limited, River Don Works, Sheffield, 9.

This beautifully produced booklet, running to 48 well-illustrated pages—some brilliantly-coloured, is meant to convince the staffs of organizations, whose job is to advise youth on the prospects offered by various types of employment in the professions, commerce and industry, of the worthwhile nature and the facilities available within the ESC group of companies. The company has set its stall out to perfection, except in one small detail, *viz.*, the Government in its recent white paper on technological education stressed that much more attention should be placed in the training of girls to become craftsmen, technicians and technologists, yet the chart on page 13 restricts itself to commercial employment for girls. The section of the booklet devoted to foundrywork is well presented, but there are no views of this department among the coloured illustrations. It is often said that it is difficult to get foundry apprentices, and it occurred to the reviewer that a brilliantly coloured illustration might have helped, as even career masters are influenced by good pictures.

Mechanical Engineering Research 1955. Published for the Department of Scientific and Industrial Research by H.M. Stationery Office, York House, Kingsway, London, W.C.2; price 4s. net.

This is a Report from the Mechanical Engineering Research Board which is presided over by Sir Andrew McCance, F.R.S. It mainly deals with the work done at East Kilbride in Scotland, and in this connection, Sir Andrew deplores the serious delays which have been experienced in the construction of the laboratories, and the completion date is likely to be at least ten years later than the latest date suggested by the original committee. Researches in progress which will later have repercussion on the foundry industry are the use of radio-active tracers in lubrication and heat transfer in pipes.

Textile Machinery Index (first edition). Published by John Worrall, Limited, Central Works, Oldham, Lancs; price £2 2s. 0d. post free.

Not being too familiar with the textile machinery industry, the reviewer sought the name of a firm famous as makers of plant for this industry. A three-line entry was found with a reference to another section (1-B) together with an obelisk to indicate that there was a displayed advertisement. Section 1-B was a full-scale entry taking up about four inches, and finally the advertisement was found. Once this has been understood, references become quite easy. It would seem that there is a case for standardization of trade directories. This directory is of use to foundries catering for the textile machinery industry.

Review of Iron and Steel Literature for 1955, by V. S. Polansky. Published by the Carnegie Library of Pittsburgh, USA.

This useful little 36-page booklet contains a section covering publications on foundry practice. The fact that the information given is taken from both American and European sources, adds to its value, although it should be remembered that it only refers to separately published books and pamphlets and does not include items in periodicals and journals.

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CLASSIFIED ADVERTISEMENTS

PREPAID RATES: Fifteen words for 7/6 (minimum charge) and 4d. per word thereafter. Box Numbers 2/6 extra (including postage of replies). Situations wanted 2d. per word.

Advertisements (accompanied by a remittance) and replies to Box Numbers should be addressed to the Advertisement Manager, Foundry Trade Journal, John Adam House, 17/19, John Adam Street, Adelphi, London, W.C.2. If received by first post Monday advertisements can normally be accommodated in the following Thursday's issue.

SITUATIONS WANTED

FOUNDRY FOREMAN seeks similar position in Light Castings Foundry. Over 30 years' experience in mechanisation, plate, jobbing. Energetic, intelligent, disciplinarian.—Box FF292, FOUNDRY TRADE JOURNAL.

FOUNDRY PRODUCTION CONTROLLER desires change to progressive position. Accustomed to medium and light casting methods, layouts, pattern control, planning and sub-contracting. Present organisation running efficiently.—Box FP307, FOUNDRY TRADE JOURNAL.

REPRESENTATIVE.—A young foundry executive, with vast industrial experience and high technical qualifications, seeks position as Technical Representative in Lancashire. Able to drive a car, and has good connections in North of England.—Box RA310, FOUNDRY TRADE JOURNAL.

CUPOLA/FOUNDRY FOREMAN desires change to Company offering sufficient remuneration and prospects to match own efficiency and ability. 20 years' practical and technical experience in all modern Foundry Practice, including converter process. Able to command respect from all employees and management through possessing outstanding personal initiative. Full responsibility; administration; labour and materials control, including costing, accountancy, and in addition can offer specialised qualifications in sports and social welfare activities. Travel anywhere. All genuine offers from reputable concerns considered, and to substantiate this advertisement, first-class references supplied.—Box CF305, FOUNDRY TRADE JOURNAL.

FOUNDRY MANAGER, experienced ferrous and non-ferrous, mechanised plant and floor work, capable complete control large foundry, seeks advancement.—Box FM304, FOUNDRY TRADE JOURNAL.

SITUATIONS VACANT

ASSISTANT FOREMAN wanted (age 25-35) for Non-ferrous Foundry in N.W. London. Must be practical foundryman.—State experience, salary, etc., Box AF289, FOUNDRY TRADE JOURNAL.

WANTED.—FOUNDRY FOREMAN. An excellent opportunity exists for an experienced Foundryman in a medium sized Non-ferrous Foundry in the Manchester area, with production of 8 to 10 tons per week. Applicants must have experience of taking charge of skilled moulders engaged on all classes of loose pattern work in all specifications of non-ferrous alloys. Experience of metal melting and CO_2 process an advantage. State age, experience, and wage required.—Box WF303, FOUNDRY TRADE JOURNAL.

ENAMELLING—VITREOUS. — Supervisory ASSISTANT and MANAGER'S DEPUTY required for busy jobbing Works. Requirements—knowledge of trade and ability to control staff. Good salary, plus bonus. Pension scheme.—Apply SECRETARY, Elm Works, Ltd., Summerstown, S.W.17. WIM. 5046.

CUPOLA Tenter for a small Cupola melting Malleable Iron.—HARDYPICK, LTD., Sheffield.

MACHINE MOULDER wanted for a small Malleable Iron Foundry.—HARDYPICK, LTD., Sheffield.

SITUATIONS VACANT—*contd.*

A FEW FURNACEMEN required for progressive Smelters and Refiners. Permanent jobs for conscientious men; liberal bonuses and Company's Pension and Life Insurance Schemes available.—Apply MITCHAM SMELTERS, LTD., Red House Road, Mitcham Road, Croydon. Tel.: THO. 6101.

FOUNDRY MANAGER required for small Foundry on South Coast, producing high class jobbing work. Practical and technical knowledge of the production of ferrous and non-ferrous castings essential. Good opportunity for keen and energetic man. Staff pension scheme available after probationary period.—Write, giving full details of past experience, Box FM290, FOUNDRY TRADE JOURNAL.

TECHNICAL AND SUPERVISORY POSITIONS.

APPLICATIONS are invited for a variety of supervisory posts ranging from FOREMAN LEVEL to ASSISTANT WORKS MANAGER and ASSISTANT METALLURGIST, required to staff a new mechanised foundry which will be working in a few months' time.

Previous experience on Blackheart Malleable castings is an advantage, but is not essential.

There is good scope for advancement and a generous Pension scheme. Apply in writing, giving details of training, previous experience, and present salary level, to:—

Managing Director,
SHOTTON BROS., LTD.,
Manchester Street, Oldbury.

LABORATORY ASSISTANT (20-22) for Grey Iron Foundry. Knowledge of general analysis essential.—Apply in writing to CHIEF CHEMIST, Harold Andrews, Sheepbridge, Ltd., Manor Lane, Halesowen, Birmingham.

IRON MOULDER, NON-FERROUS MOULDER, and IRON MACHINE MOULDER wanted.—MOYLE, Kingston-on-Thames.

SITE ENGINEER required to supervise the erection of a group of Foundries in India. 3 years' contract. Good salary. Accommodation and tax concessions to suitable candidate.—Box SE296, FOUNDRY TRADE JOURNAL.

STEEL FOUNDRY GENERAL FOREMAN (Assistant Manager) required by a large Canadian company with diversified foundry operations on castings for heavy machinery. Steel castings output 350 to 700 tons monthly from small, machine moulded up to pit work weighing 12 tons and over. Recently built, well equipped foundry. Principal duties to assist Superintendent by supervising departmental foremen in the fields of daily operation and handling of working force, production to schedules, labour and overhead costs. Incentive plan for working force and foremen. Should be familiar with present day methods and able to train personnel. Must be qualified as a potential superintendent. Passage assisted. Box SF248, FOUNDRY TRADE JOURNAL.

SITUATIONS VACANT—*contd.*

THE INDIAN IRON & STEEL CO., LTD., invite applications from SENIOR FOUNDRY EXECUTIVES of Indian nationality. Applicants should have had at least 10 years' practical experience in iron or steel founding, and preference will be given to those applicants who have had training in overseas foundries and who have had managerial experience. Salary will be according to qualifications and ability to accept responsibility at high levels.—Apply by letter only to MARTIN BURN, LTD. (London Agency), 71, Queen Street, London, E.C.4, giving full details of education and experience and stating age.

The British Cast Iron Research Association

OPERATIONAL RESEARCH TEAM.

AN appointment will shortly be made to the Operational Research Team of a young man with suitable foundry experience and technical knowledge. The objectives of the Team are to advise those foundries which request such assistance, on means of increasing productivity and production efficiency. A memorandum giving details of the post, and a form of application, will be forwarded on application to the Secretary, B.C.I.R.A., Bordesley Hall, Alvechurch, Birmingham.

British Cast Iron Research Association
Bordesley Hall,
Alvechurch, Birmingham.

CAST IRON RESEARCH.

THE MOND NICKEL CO., LTD., requires, in its Birmingham Laboratory, a METALLURGIST for research into the properties of spheroidal graphite and alloy cast irons. Applicants should preferably have some research experience either in the field of cast irons or steels. A good metallurgical degree or equivalent qualification is desirable.

Salary will be in accordance with experience and qualifications. Pension and insurance schemes are in operation and, in appropriate cases, assistance can be given for housing.

Applications, giving details of age, qualifications, and experience, should be addressed to:

THE MANAGER,
Development and Research Dept.,
THE MOND NICKEL CO., LTD.,
Thames House, Millbank, London, S.W.1.

Mark envelope "Confidential L.32."